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HIGH SCHOOL APPRENTICESHIP PROGRAM FINAL REPORTS

VOLUME 16

ARNOLD ENGINEERING DEVELOPMENT CENTER

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13. ABSTRACT *(Maximum 200 words)*
The United States Air Force Summer Research Program (USAF-SRP) is designed to introduce university, college, and technical institute faculty members, graduate students, and high school students to Air Force research. This is accomplished by the faculty members (Summer Faculty Research Program, (SFRP)), graduate students (Graduate Student Research Program (GSRP)), and high school students (High School Apprenticeship Program (HSAP)) being selected on a nationally advertised competitive basis during the summer intersession period to perform research at Air Force Research Laboratory (AFRL) Technical Directorates, Air Force Air Logistics Centers (ALC), and other AF Laboratories. This volume consists of a program overview, program management statistics, and the final technical reports from the HSAP participants at the Arnold Engineering Development Center.

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PREFACE

Reports in this volume are numbered consecutively beginning with number 1. Each report is paginated with the report number followed by consecutive page numbers, e.g., 1-1, 1-2, 1-3; 2-1, 2-2, 2-3.

This document is one of a set of 16 volumes describing the 1996 AFOSR Summer Research Program. The following volumes comprise the set:

VOLUME	TITLE
1	Program Management Report
	Summer Faculty Research Program (SFRP) Reports
2A & 2B	Armstrong Laboratory
3A & 3B	Phillips Laboratory
4	Rome Laboratory
5A, 5B & 5C	Wright Laboratory
6	Arnold Engineering Development Center, Wilford Hall Medical Center and Air Logistics Centers
	Graduate Student Research Program (GSRP) Reports
7A & 7B	Armstrong Laboratory
8	Phillips Laboratory
9	Rome Laboratory
10A & 10B	Wright Laboratory
11	Arnold Engineering Development Center, United States Air Force Academy, Wilford Hall Medical Center and Wright Patterson Medical Center
	High School Apprenticeship Program (HSAP) Reports
12A & 12B	Armstrong Laboratory
13	Phillips Laboratory
14	Rome Laboratory
15A&15B	Wright Laboratory
16	Arnold Engineering Development Center

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INTRODUCTION

The Summer Research Program (SRP), sponsored by the Air Force Office of Scientific Research (AFOSR), offers paid opportunities for university faculty, graduate students, and high school students to conduct research in U.S. Air Force research laboratories nationwide during the summer.

Introduced by AFOSR in 1978, this innovative program is based on the concept of teaming academic researchers with Air Force scientists in the same disciplines using laboratory facilities and equipment not often available at associates' institutions.

The Summer Faculty Research Program (SFRP) is open annually to approximately 150 faculty members with at least two years of teaching and/or research experience in accredited U.S. colleges, universities, or technical institutions. SFRP associates must be either U.S. citizens or permanent residents.

The Graduate Student Research Program (GSRP) is open annually to approximately 100 graduate students holding a bachelor's or a master's degree; GSRP associates must be U.S. citizens enrolled full time at an accredited institution.

The High School Apprentice Program (HSAP) annually selects about 125 high school students located within a twenty mile commuting distance of participating Air Force laboratories.

AFOSR also offers its research associates an opportunity, under the Summer Research Extension Program (SREP), to continue their AFOSR-sponsored research at their home institutions through the award of research grants. In 1994 the maximum amount of each grant was increased from \$20,000 to \$25,000, and the number of AFOSR-sponsored grants decreased from 75 to 60. A separate annual report is compiled on the SREP.

The numbers of projected summer research participants in each of the three categories and SREP "grants" are usually increased through direct sponsorship by participating laboratories.

AFOSR's SRP has well served its objectives of building critical links between Air Force research laboratories and the academic community, opening avenues of communications and forging new research relationships between Air Force and academic technical experts in areas of national interest, and strengthening the nation's efforts to sustain careers in science and engineering. The success of the SRP can be gauged from its growth from inception (see Table 1) and from the favorable responses the 1996 participants expressed in end-of-tour SRP evaluations (Appendix B).

AFOSR contracts for administration of the SRP by civilian contractors. The contract was first awarded to Research & Development Laboratories (RDL) in September 1990. After

completion of the 1990 contract, RDL (in 1993) won the recompetition for the basic year and four 1-year options.

2. PARTICIPATION IN THE SUMMER RESEARCH PROGRAM

The SRP began with faculty associates in 1979; graduate students were added in 1982 and high school students in 1986. The following table shows the number of associates in the program each year.

YEAR	SRP Participation, by Year			TOTAL
	SFRP	GSRP	HSAP	
1979	70			70
1980	87			87
1981	87			87
1982	91	17		108
1983	101	53		154
1984	152	84		236
1985	154	92		246
1986	158	100	42	300
1987	159	101	73	333
1988	153	107	101	361
1989	168	102	103	373
1990	165	121	132	418
1991	170	142	132	444
1992	185	121	159	464
1993	187	117	136	440
1994	192	117	133	442
1995	190	115	137	442
1996	188	109	138	435

Beginning in 1993, due to budget cuts, some of the laboratories weren't able to afford to fund as many associates as in previous years. Since then, the number of funded positions has remained fairly constant at a slightly lower level.

3. RECRUITING AND SELECTION

The SRP is conducted on a nationally advertised and competitive-selection basis. The advertising for faculty and graduate students consisted primarily of the mailing of 8,000 52-page SRP brochures to chairpersons of departments relevant to AFOSR research and to administrators of grants in accredited universities, colleges, and technical institutions. Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs) were included. Brochures also went to all participating USAF laboratories, the previous year's participants, and numerous individual requesters (over 1000 annually).

RDL placed advertisements in the following publications: *Black Issues in Higher Education, Winds of Change,* and *IEEE Spectrum.* Because no participants list either *Physics Today* or *Chemical & Engineering News* as being their source of learning about the program for the past several years, advertisements in these magazines were dropped, and the funds were used to cover increases in brochure printing costs.

High school applicants can participate only in laboratories located no more than 20 miles from their residence. Tailored brochures on the HSAP were sent to the head counselors of 180 high schools in the vicinity of participating laboratories, with instructions for publicizing the program in their schools. High school students selected to serve at Wright Laboratory's Armament Directorate (Eglin Air Force Base, Florida) serve eleven weeks as opposed to the eight weeks normally worked by high school students at all other participating laboratories.

Each SFRP or GSRP applicant is given a first, second, and third choice of laboratory. High school students who have more than one laboratory or directorate near their homes are also given first, second, and third choices.

Laboratories make their selections and prioritize their nominees. AFOSR then determines the number to be funded at each laboratory and approves laboratories' selections.

Subsequently, laboratories use their own funds to sponsor additional candidates. Some selectees do not accept the appointment, so alternate candidates are chosen. This multi-step selection procedure results in some candidates being notified of their acceptance after scheduled deadlines. The total applicants and participants for 1996 are shown in this table.

1996 Applicants and Participants			
PARTICIPANT CATEGORY	TOTAL APPLICANTS	SELECTEES	DECLINING SELECTEES
SFRP	572	188	39
(HBCU/MI)	(119)	(27)	(5)
GSRP	235	109	7
(HBCU/MI)	(18)	(7)	(1)
HSAP	474	138	8
TOTAL	1281	435	54

4. SITE VISITS

During June and July of 1996, representatives of both AFOSR/NI and RDL visited each participating laboratory to provide briefings, answer questions, and resolve problems for both laboratory personnel and participants. The objective was to ensure that the SRP would be as constructive as possible for all participants. Both SRP participants and RDL representatives found these visits beneficial. At many of the laboratories, this was the only opportunity for all participants to meet at one time to share their experiences and exchange ideas.

5. HISTORICALLY BLACK COLLEGES AND UNIVERSITIES AND MINORITY INSTITUTIONS (HBCU/MIs)

Before 1993, an RDL program representative visited from seven to ten different HBCU/MIs annually to promote interest in the SRP among the faculty and graduate students. These efforts were marginally effective, yielding a doubling of HBCI/MI applicants. In an effort to achieve AFOSR's goal of 10% of all applicants and selectees being HBCU/MI qualified, the RDL team decided to try other avenues of approach to increase the number of qualified applicants. Through the combined efforts of the AFOSR Program Office at Bolling AFB and RDL, two very active minority groups were found, HACU (Hispanic American Colleges and Universities) and AISES (American Indian Science and Engineering Society). RDL is in communication with representatives of each of these organizations on a monthly basis to keep up with the their activities and special events. Both organizations have widely-distributed magazines/quarterlies in which RDL placed ads.

Since 1994 the number of both SFRP and GSRP HBCU/MI applicants and participants has increased ten-fold, from about two dozen SFRP applicants and a half dozen selectees to over 100 applicants and two dozen selectees, and a half-dozen GSRP applicants and two or three selectees to 18 applicants and 7 or 8 selectees. Since 1993, the SFRP had a two-fold applicant

increase and a two-fold selectee increase. Since 1993, the GSRP had a three-fold applicant increase and a three to four-fold increase in selectees.

In addition to RDL's special recruiting efforts, AFOSR attempts each year to obtain additional funding or use leftover funding from cancellations the past year to fund HBCU/MI associates. This year, 5 HBCU/MI SFRPs declined after they were selected (and there was no one qualified to replace them with). The following table records HBCU/MI participation in this program.

SRP HBCU/MI Participation, By Year				
YEAR	**SFRP**		**GSRP**	
	Applicants	**Participants**	**Applicants**	**Participants**
1985	76	23	15	11
1986	70	18	20	10
1987	82	32	32	10
1988	53	17	23	14
1989	39	15	13	4
1990	43	14	17	3
1991	42	13	8	5
1992	70	13	9	5
1993	60	13	6	2
1994	90	16	11	6
1995	90	21	20	8
1996	119	27	18	7

6. SRP FUNDING SOURCES

Funding sources for the 1996 SRP were the AFOSR-provided slots for the basic contract and laboratory funds. Funding sources by category for the 1996 SRP selected participants are shown here.

1996 SRP FUNDING CATEGORY	SFRP	GSRP	HSAP
AFOSR Basic Allocation Funds	141	85	123
USAF Laboratory Funds	37	19	15
HBCU/MI By AFOSR (Using Procured Addn'l Funds)	10	5	0
TOTAL	188	109	138

SFRP - 150 were selected, but nine canceled too late to be replaced.
GSRP - 90 were selected, but five canceled too late to be replaced (10 allocations for the ALCs were withheld by AFOSR.)
HSAP - 125 were selected, but two canceled too late to be replaced.

7. COMPENSATION FOR PARTICIPANTS

Compensation for SRP participants, per five-day work week, is shown in this table.

1996 SRP Associate Compensation

PARTICIPANT CATEGORY	1991	1992	1993	1994	1995	1996
Faculty Members	$690	$718	$740	$740	$740	$770
Graduate Student (Master's Degree)	$425	$442	$455	$455	$455	$470
Graduate Student (Bachelor's Degree)	$365	$380	$391	$391	$391	$400
High School Student (First Year)	$200	$200	$200	$200	$200	$200
High School Student (Subsequent Years)	$240	$240	$240	$240	$240	$240

The program also offered associates whose homes were more than 50 miles from the laboratory an expense allowance (seven days per week) of $50/day for faculty and $40/day for graduate students. Transportation to the laboratory at the beginning of their tour and back to their home destinations at the end was also reimbursed for these participants. Of the combined SFRP and

GSRP associates, 65 % (194 out of 297) claimed travel reimbursements at an average round-trip cost of $780.

Faculty members were encouraged to visit their laboratories before their summer tour began. All costs of these orientation visits were reimbursed. Forty-five percent (85 out of 188) of faculty associates took orientation trips at an average cost of $444. By contrast, in 1993, 58 % of SFRP associates took orientation visits at an average cost of $685; that was the highest percentage of associates opting to take an orientation trip since RDL has administered the SRP, and the highest average cost of an orientation trip. These 1993 numbers are included to show the fluctuation which can occur in these numbers for planning purposes.

Program participants submitted biweekly vouchers countersigned by their laboratory research focal point, and RDL issued paychecks so as to arrive in associates' hands two weeks later.

In 1996, RDL implemented direct deposit as a payment option for SFRP and GSRP associates. There were some growing pains. Of the 128 associates who opted for direct deposit, 17 did not check to ensure that their financial institutions could support direct deposit (and they couldn't), and eight associates never did provide RDL with their banks' ABA number (direct deposit bank routing number), so only 103 associates actually participated in the direct deposit program. The remaining associates received their stipend and expense payments via checks sent in the US mail.

HSAP program participants were considered actual RDL employees, and their respective state and federal income tax and Social Security were withheld from their paychecks. By the nature of their independent research, SFRP and GSRP program participants were considered to be consultants or independent contractors. As such, SFRP and GSRP associates were responsible for their own income taxes, Social Security, and insurance.

8. CONTENTS OF THE 1996 REPORT

The complete set of reports for the 1996 SRP includes this program management report (Volume 1) augmented by fifteen volumes of final research reports by the 1996 associates, as indicated below:

1996 SRP Final Report Volume Assignments

LABORATORY	SFRP	GSRP	HSAP
Armstrong	2	7	12
Phillips	3	8	13
Rome	4	9	14
Wright	5A, 5B	10	15
AEDC, ALCs, WHMC	6	11	16

APPENDIX A – PROGRAM STATISTICAL SUMMARY

A. Colleges/Universities Represented

Selected SFRP associates represented 169 different colleges, universities, and institutions, GSRP associates represented 95 different colleges, universities, and institutions.

B. States Represented

SFRP -Applicants came from 47 states plus Washington D.C. and Puerto Rico. Selectees represent 44 states plus Puerto Rico.

GSRP - Applicants came from 44 states and Puerto Rico. Selectees represent 32 states.

HSAP - Applicants came from thirteen states. Selectees represent nine states.

Total Number of Participants	
SFRP	188
GSRP	109
HSAP	138
TOTAL	435

Degrees Represented			
	SFRP	GSRP	TOTAL
Doctoral	184	1	185
Master's	4	48	52
Bachelor's	0	60	60
TOTAL	188	109	297

SFRP Academic Titles	
Assistant Professor	79
Associate Professor	59
Professor	42
Instructor	3
Chairman	0
Visiting Professor	1
Visiting Assoc. Prof.	0
Research Associate	4
TOTAL	188

Source of Learning About the SRP		
Category	Applicants	Selectees
Applied/participated in prior years	28%	34%
Colleague familiar with SRP	19%	16%
Brochure mailed to institution	23%	17%
Contact with Air Force laboratory	17%	23%
IEEE Spectrum	2%	1%
BIIHE	1%	1%
Other source	10%	8%
TOTAL	100%	100%

APPENDIX B – SRP EVALUATION RESPONSES

1. OVERVIEW

Evaluations were completed and returned to RDL by four groups at the completion of the SRP. The number of respondents in each group is shown below.

Table B-1. Total SRP Evaluations Received

Evaluation Group	Responses
SFRP & GSRPs	275
HSAPs	113
USAF Laboratory Focal Points	84
USAF Laboratory HSAP Mentors	6

All groups indicate unanimous enthusiasm for the SRP experience.

The summarized recommendations for program improvement from both associates and laboratory personnel are listed below:

A. Better preparation on the labs' part prior to associates' arrival (i.e., office space, computer assets, clearly defined scope of work).

B. Faculty Associates suggest higher stipends for SFRP associates.

C. Both HSAP Air Force laboratory mentors and associates would like the summer tour extended from the current 8 weeks to either 10 or 11 weeks; the groups state it takes 4-6 weeks just to get high school students up-to-speed on what's going on at laboratory. (Note: this same argument was used to raise the faculty and graduate student participation time a few years ago.)

2. 1996 USAF LABORATORY FOCAL POINT (LFP) EVALUATION RESPONSES

The summarized results listed below are from the 84 LFP evaluations received.

1. LFP evaluations received and associate preferences:

Table B-2. Air Force LFP Evaluation Responses (By Type)

		How Many Associates Would You Prefer To Get ? (% Response)											
		SFRP				GSRP (w/Univ Professor)				GSRP (w/o Univ Professor)			
Lab	Evals Recv'd	0	1	2	3+	0	1	2	3+	0	1	2	3+
AEDC	0	-	-	-	-	-	-	-	-	-	-	-	-
WHMC	0	-	-	-	-	-	-	-	-	-	-	-	-
AL	7	28	28	28	14	54	14	28	0	86	0	14	0
FJSRL	1	0	100	0	0	100	0	0	0	0	100	0	0
PL	25	40	40	16	4	88	12	0	0	84	12	4	0
RL	5	60	40	0	0	80	10	0	0	100	0	0	0
WL	46	30	43	20	6	78	17	4	0	93	4	2	0
Total	84	32%	50%	13%	5%	80%	11%	6%	0%	73%	23%	4%	0%

LFP Evaluation Summary. The summarized responses, by laboratory, are listed on the following page. LFPs were asked to rate the following questions on a scale from 1 (below average) to 5 (above average).

2. LFPs involved in SRP associate application evaluation process:
   a. Time available for evaluation of applications:
   b. Adequacy of applications for selection process:
3. Value of orientation trips:
4. Length of research tour:
5 a. Benefits of associate's work to laboratory:
   b. Benefits of associate's work to Air Force:
6. a. Enhancement of research qualifications for LFP and staff:
   b. Enhancement of research qualifications for SFRP associate:
   c. Enhancement of research qualifications for GSRP associate:
7. a. Enhancement of knowledge for LFP and staff:
   b. Enhancement of knowledge for SFRP associate:
   c. Enhancement of knowledge for GSRP associate:
8. Value of Air Force and university links:
9. Potential for future collaboration:
10. a. Your working relationship with SFRP:
    b. Your working relationship with GSRP:
11. Expenditure of your time worthwhile:

(Continued on next page)

12. Quality of program literature for associate:
13. a. Quality of RDL's communications with you:
    b. Quality of RDL's communications with associates:
14. Overall assessment of SRP:

Table B-3. Laboratory Focal Point Reponses to above questions

	AEDC	*AL*	*FJSRL*	*PL*	*RL*	*WHMC*	*WL*
# Evals Recv'd	0	7	1	14	5	0	46
Question #							
2	-	86 %	0 %	88 %	80 %	-	85 %
2a	-	4.3	n/a	3.8	4.0	-	3.6
2b	-	4.0	n/a	3.9	4.5	-	4.1
3	-	4.5	n/a	4.3	4.3	-	3.7
4	-	4.1	4.0	4.1	4.2	-	3.9
5a	-	4.3	5.0	4.3	4.6	-	4.4
5b	-	4.5	n/a	4.2	4.6	-	4.3
6a	-	4.5	5.0	4.0	4.4	-	4.3
6b	-	4.3	n/a	4.1	5.0	-	4.4
6c	-	3.7	5.0	3.5	5.0	-	4.3
7a	-	4.7	5.0	4.0	4.4	-	4.3
7b	-	4.3	n/a	4.2	5.0	-	4.4
7c	-	4.0	5.0	3.9	5.0	-	4.3
8	-	4.6	4.0	4.5	4.6	-	4.3
9	-	4.9	5.0	4.4	4.8	-	4.2
10a	-	5.0	n/a	4.6	4.6	-	4.6
10b	-	4.7	5.0	3.9	5.0	-	4.4
11	-	4.6	5.0	4.4	4.8	-	4.4
12	-	4.0	4.0	4.0	4.2	-	3.8
13a	-	3.2	4.0	3.5	3.8	-	3.4
13b	-	3.4	4.0	3.6	4.5	-	3.6
14	-	4.4	5.0	4.4	4.8	-	4.4

3. 1996 SFRP & GSRP EVALUATION RESPONSES

The summarized results listed below are from the 257 SFRP/GSRP evaluations received.

Associates were asked to rate the following questions on a scale from 1 (below average) to 5 (above average) - by Air Force base results and over-all results of the 1996 evaluations are listed after the questions.

1. The match between the laboratories research and your field:
2. Your working relationship with your LFP:
3. Enhancement of your academic qualifications:
4. Enhancement of your research qualifications:
5. Lab readiness for you: LFP, task, plan:
6. Lab readiness for you: equipment, supplies, facilities:
7. Lab resources:
8. Lab research and administrative support:
9. Adequacy of brochure and associate handbook:
10. RDL communications with you:
11. Overall payment procedures:
12. Overall assessment of the SRP:
13. a. Would you apply again?
    b. Will you continue this or related research?
14. Was length of your tour satisfactory?
15. Percentage of associates who experienced difficulties in finding housing:
16. Where did you stay during your SRP tour?
    a. At Home:
    b. With Friend:
    c. On Local Economy:
    d. Base Quarters:
17. Value of orientation visit:
    a. Essential:
    b. Convenient:
    c. Not Worth Cost:
    d. Not Used:

SFRP and GSRP associate's responses are listed in tabular format on the following page.

Table B-4. 1996 SFRP & GSRP Associate Responses to SRP Evaluation

	Arnold	Brooks	Edwards	Eglin	Griffis	Hanscom	Kelly	Kirtland	Lackland	Robins	Tyndall	WPAFB	average
# res	6	48	6	14	31	19	3	32	1	2	10	85	257
1	4.8	4.4	4.6	4.7	4.4	4.9	4.6	4.6	5.0	5.0	4.0	4.7	4.6
2	5.0	4.6	4.1	4.9	4.7	4.7	5.0	4.7	5.0	5.0	4.6	4.8	4.7
3	4.5	4.4	4.0	4.6	4.3	4.2	4.3	4.4	5.0	5.0	4.5	4.3	4.4
4	4.3	4.5	3.8	4.6	4.4	4.4	4.3	4.6	5.0	4.0	4.4	4.5	4.5
5	4.5	4.3	3.3	4.8	4.4	4.5	4.3	4.2	5.0	5.0	3.9	4.4	4.4
6	4.3	4.3	3.7	4.7	4.4	4.5	4.0	3.8	5.0	5.0	3.8	4.2	4.2
7	4.5	4.4	4.2	4.8	4.5	4.3	4.3	4.1	5.0	5.0	4.3	4.3	4.4
8	4.5	4.6	3.0	4.9	4.4	4.3	4.3	4.5	5.0	5.0	4.7	4.5	4.5
9	4.7	4.5	4.7	4.5	4.3	4.5	4.7	4.3	5.0	5.0	4.1	4.5	4.5
10	4.2	4.4	4.7	4.4	4.1	4.1	4.0	4.2	5.0	4.5	3.6	4.4	4.3
11	3.8	4.1	4.5	4.0	3.9	4.1	4.0	4.0	3.0	4.0	3.7	4.0	4.0
12	5.7	4.7	4.3	4.9	4.5	4.9	4.7	4.6	5.0	4.5	4.6	4.5	4.6
Numbers below are percentages													
13a	83	90	83	93	87	75	100	81	100	100	100	86	87
13b	100	89	83	100	94	98	100	94	100	100	100	94	93
14	83	96	100	90	87	80	100	92	100	100	70	84	88
15	17	6	0	33	20	76	33	25	0	100	20	8	39
16a	-	26	17	9	38	23	33	4	-	-	-	30	
16b	100	33	-	40	-	8	-	-	-	-	36	2	
16c	-	41	83	40	62	69	67	96	100	100	64	68	
16d	-	-	-	-	-	-	-	-	-	-	-	0	
17a	-	33	100	17	50	14	67	39	-	50	40	31	35
17b	-	21	-	17	10	14	-	24	-	50	20	16	16
17c	-	-	-	-	10	7	-	-	-	-	-	2	3
17d	100	46	-	66	30	69	33	37	100	-	40	51	46

4. 1996 USAF LABORATORY HSAP MENTOR EVALUATION RESPONSES

Not enough evaluations received (5 total) from Mentors to do useful summary.

5. 1996 HSAP EVALUATION RESPONSES

The summarized results listed below are from the 113 HSAP evaluations received.

HSAP apprentices were asked to rate the following questions on a scale from 1 (below average) to 5 (above average)

1. Your influence on selection of topic/type of work.
2. Working relationship with mentor, other lab scientists.
3. Enhancement of your academic qualifications.
4. Technically challenging work.
5. Lab readiness for you: mentor, task, work plan, equipment.
6. Influence on your career.
7. Increased interest in math/science.
8. Lab research & administrative support.
9. Adequacy of RDL's Apprentice Handbook and administrative materials.
10. Responsiveness of RDL communications.
11. Overall payment procedures.
12. Overall assessment of SRP value to you.
13. Would you apply again next year? Yes (92 %)
14. Will you pursue future studies related to this research? Yes (68 %)
15. Was Tour length satisfactory? Yes (82 %)

	Arnold	Brooks	Edwards	Eglin	Griffiss	Hanscom	Kirtland	Tyndall	WPAFB	Totals
# resp	5	19	7	15	13	2	7	5	40	113
1	2.8	3.3	3.4	3.5	3.4	4.0	3.2	3.6	3.6	3.4
2	4.4	4.6	4.5	4.8	4.6	4.0	4.4	4.0	4.6	4.6
3	4.0	4.2	4.1	4.3	4.5	5.0	4.3	4.6	4.4	4.4
4	3.6	3.9	4.0	4.5	4.2	5.0	4.6	3.8	4.3	4.2
5	4.4	4.1	3.7	4.5	4.1	3.0	3.9	3.6	3.9	4.0
6	3.2	3.6	3.6	4.1	3.8	5.0	3.3	3.8	3.6	3.7
7	2.8	4.1	4.0	3.9	3.9	5.0	3.6	4.0	4.0	3.9
8	3.8	4.1	4.0	4.3	4.0	4.0	4.3	3.8	4.3	4.2
9	4.4	3.6	4.1	4.1	3.5	4.0	3.9	4.0	3.7	3.8
10	4.0	3.8	4.1	3.7	4.1	4.0	3.9	2.4	3.8	3.8
11	4.2	4.2	3.7	3.9	3.8	3.0	3.7	2.6	3.7	3.8
12	4.0	4.5	4.9	4.6	4.6	5.0	4.6	4.2	4.3	4.5
Numbers below are percentages										
13	60%	95%	100%	100%	85%	100%	100%	100%	90%	92%
14	20%	80%	71%	80%	54%	100%	71%	80%	65%	68%
15	100%	70%	71%	100%	100%	50%	86%	60%	80%	82%

OPERATING MAP PREPARATION USING ARC HEATER CORRELATIONS

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Final Report for:
High School Apprentice Program

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Arnold Engineering Development Center

July 1996

OPERATING MAP PREPARATION USING
ARC HEATER CORRELATIONS

Sara Elizabeth Allen
Coffee County Central High School

ABSTRACT

Arc heater correlations are used to predict new operating points for existing arc heaters and to predict how a new scaled up arc heater will operate. Preparations of arc heater operating maps take on the form of Pressure vs. Enthalpy and Voltage vs. Current plots. There are two methods of generating these plots: dimensional and non-dimensional correlations. Although there is only one way to determine the non-dimensional equations, there are five ways to determine the dimensional equations. By graphing all the different dimensional and non-dimensional choices for two different data sets and projecting one up to the other, it was determined that the non-dimensional method is the more accurate for any data set. However, any method works fine for a data set with very little scatter.

OPERATING MAP PREPARATION USING ARC HEATER CORRELATIONS

Sara Elizabeth Allen

INTRODUCTION

An arc heater is a device that uses an electrical current to heat air to very high temperatures. An arc is stretched down the length of the constrictor from an anode to a cathode as shown in Figure 1. Air is forced through the constrictor and becomes heated by the electrical arc. The heater constrictor is made of many segments that are insulated from each other to prevent the arc from traveling down the wall of the constrictor. Also, air is injected tangentially to the inside wall to create a vortex to help stabilize the arc. Water is pumped internally through the segments to keep them from melting. The H3 heater has a 3 inch diameter constrictor and the H1 heater has a 2 inch diameter constrictor. The H3 is the newest addition to the AEDC facilities.

Arc heaters have several different uses. They are used in industry as well as aerospace testing. Since arc heaters can maintain such high temperatures for relatively long periods of time, they are often used to simulate atmospheric reentry conditions.

Scaling relations are needed to develop new arc heaters as well as to use established ones. Scaling relations developed from existing heaters are employed to predict how a new and larger heater will behave. Operating maps are often generated from these scaling relations for ease of use when setting up a new arc heater operating condition. It is of the utmost importance that the scaling relations be as accurate as possible, or it will not be possible to achieve a desired operating point.

DISCUSSION OF PROBLEM

Preparation of arc heater operating maps from correlation equations take on the form of Pressure vs. Enthalpy and Voltage vs. Current plots. There are two methods of generating these plots: dimensional and non-dimensional. The non-dimensional correlations use pi-factors, derived from the Buckingham Pi Theorem, to determine the equations. There is only one way to use the non-dimensional equations to generate an operating map. The dimensional correlations are direct curve fits that use a previous data base to generate a line. The resulting dimensional equations can be combined in several different ways to generate an operating map. The question is not only which method is more accurate, but which of the dimensional choices is more accurate.

METHODOLOGY

Once the non-dimensional equations are derived, the operating maps are straightforward. There is no deviation from them. Typical non-dimensional equations are shown in Figure 2. However, there are five options for the dimensional equations (see Table I); two of these options, A and E (Operating Map 1, Table I), are for the Pressure vs. Enthalpy plots, and three of these options, B, C and D (Operating Map 2, Table I), are for the Voltage vs. Current plots. After graphing all five dimensional options and the non-dimensional option for the H3 data (a 34 point database whose geometry parameters are shown in Table II) H3 points from Table IV were added to the graphs to test their accuracy. The next step used a combined data set from other smaller heaters to predict the already known H3 data points. This combined data set is a 91 point sample of experimental data obtained in segmented-type heaters; 47 points are from the H1 heater (2 inch constrictor diameter) and the

rest are from other smaller heaters. Table III shows the geometry parameters for this database. After all the graphs are drawn a comparison is made. Since the projection is of the H3 data points, the answer is already known; it is now possible to see which method gives the best projection.

RESULTS

Correlations using the non-dimensional method are shown in Figure 2. Results are shown for the 1 and 2 inch diameter constrictors and also for the 3 inch diameter constrictor (H3). It is noted that H3 points generally fall within the data scatter of the 1 and 2 inch data. H3 points have less scatter than do the 1 and 2 inch data. Also, the correlation for the H3 data alone is somewhat different. Since the H3 data set appears to be very consistent, it will be used for the initial evaluation of the various methods for predicting operating maps.

Operating maps generated from the non-dimensional correlations are shown in Figure 3a (Pressure vs. Enthalpy with lines of constant mass flow and current) and in Figure 3b (Voltage vs. Current with lines of constant enthalpy and pressure). Because the graphs show a projection of H3 data, selected points from the H3 database (Table IV) have been added to show the accuracy of the non-dimensional method. Similar operating maps can be generated from the dimensional correlations according to the options listed in Table I. These are not shown in their entirety here; instead selected operating maps are compared in Figures 4 and 5.

Operating maps for the H3 arc heater with a 1.35 inch diameter throat are compared in Figure 4. A current level of 1800 amps was selected for the Pressure vs. Enthalpy operating map comparison shown in Figure 4a. First, projected curves are compared based on H3

correlations (see Table II). The three curves shown based on non-dimensional, dimensional option A and dimensional option E are seen to give nearly the same results. The two data points shown indicate good agreement. Secondly, projected curves were compared based on the 91 point data base (see Table III). It is seen that the non-dimensional and the dimensional option A predictions agree fairly well, but tend to over-predict the enthalpy by approximately 12%. The dimensional option E result is seen to still further over-predict the enthalpy by 25%. This would seem to indicate that option E is not a desirable option to use.

A similar analysis was done with the Voltage vs. Current operating map in Figure 4b. Here, an enthalpy of 3000 Btu/lbm was selected for the comparison. Again using correlations based on only H3 data yielded results that agreed quite well with the non-dimensional correlations and the dimensional options B, C & D correlations as well as the with the experimental points. When correlations based on the 91 point data base were used it was found that the non-dimensional result and the dimensional option B result were in agreement but over-predicted the voltage for a given current by some 28%. The dimensional options D & C are seen not only to further over-predict the voltage but also to have a different slope as well. Hence dimensional options D or C are the least desirable.

Similar results are shown in Figure 5 for the H3 arc heater with a 1.65 inch diameter throat. Similar conclusions can be drawn showing that the conclusions are independent of throat size.

CONCLUSION

Operating maps are useful for predicting new operating points for an existing arc heater. The following observations can be made

concerning the H3 arc heater. Since the H3 data set has very little scatter, all of the options considered produced acceptable operating maps. However, when predicting a new operating point for the H3 arc heater it is best to use operating maps based on H3 data only.

Operating maps can also be used to predict how a new scaled-up arc heater will operate. Various options for this process were tested by using 1 inch and 2 inch diameter constrictor data to predict the operation of a 3 inch diameter heater (H3). The following is observed. The non-dimensional correlations and the dimensional correlation options A & B produced similar operating maps but were 10% or more in error when predicting H3 operating points. Dimensional correlation options C, D & E produced operating maps even more in error and hence are not recommended for use. Also, since the non-dimensional correlations do not require an extrapolation of the curve-fit relations they are less subject to error caused by considerable scatter in the data base.

Table I Options for generating Operating Maps with Dimensional correlations

Operating map #1

P vs. H with I, m as parameters

Option A

To plot lines of m=const, use $H_o=f(P_{ch},m,D^*,D_c,L)$

To plot lines of I=const, use $H_o=f(P_{ch},I,D^*,D_c,L)$

Option E

To plot lines of m=const, use $H_o=f(P_{ch},m,D^*,D_c,L)$

To plot lines of I=const, use $I=f(P_{ch},H_o,D^*,D_c,L)$

(invert algebraically to solve for H_o)

Operating map #2

V vs. I with P_{ch}, H_o as parameters

Option B

To plot lines of P_{ch}=const, use $V=f(P_{ch},I,D^*,D_c,L)$

To plot lines of H_o=const, use $H_o=f(P_{ch},I,D^*,D_c,L)$

(invert algebraically to solve for I)

Option C

To plot lines of P_{ch}=const, use $V=f(P_{ch},I,D^*,D_c,L)$

To plot lines of H_o=const, use $I=f(P_{ch},H_o,D^*,D_c,L)$

Option D

To plot lines of P_{ch}=const, use $V=f(P_{ch},H_o,D^*,D_c,L)$

To plot lines of H_o=const, use $I=f(P_{ch},H_o,D^*,D_c,L)$

Table II 34 point data base for H3

Parameter	Range in Database
Length, L	96 in.
Chamber Diameter, D_c	3 in.
Throat Size, D*	1.35 & 1.65 in.
Pressure, P_{ch}	23.7-119.02 atm
Enthalpy, H_B	2462-4680 Btu/lbm
Mass Flow, m	2.894-18.17 lbm/sec
Voltage, V	12.02-29.75 kV
Current, I	978-2707 amp

Table III 91 point data base for 1"&2" diameter constrictors

Parameter	Range in Database
Length, L	10-64 in.
Chamber Diameter, D_c	0.9-2.0 in.
Throat Size, D*	.275-1.156 in.
Pressure, P_{ch}	22-155 atm
Enthalpy, H_B	1750-6990 Btu/lbm
Mass Flow, m	0.055-10.54 lbm/sec
Voltage, V	1.6-28.5 kV
Current, I	370-1160 amp

Table IV H3 data points

D*=1.35				
Point #	Enthalpy	Pressure	Current	Voltage
1-003	2810	24.1	976	12.4
1-009	3210	45.2	1550	16.6
1-010	3520	46.9	1885	15.9
1-016	2940	88.9	2040	23.9
1-022	2970	103.7	2270	25.6
2-003	4000	49.3	2233	16.0
2-044	2684	119.0	1983	29.8
2-046	2990	106.6	2175	27.1
2-048	2600	100.0	1720	28.1
D*=1.65				
Point #	Enthalpy	Pressure	Current	Voltage
2-019	2980	23.5	1500	12.7
2-020	3540	25.3	1793	12.7
2-022	4220	27.2	2370	12.1
2-025	2670	45.5	1840	18.0
2-027	3240	50.0	2350	18.1
2-029	2500	68.8	2115	22.5
2-032	2530	81.5	2290	24.6
2-033	2470	80.7	2140	25.3
2-036	2950	83.6	2707	24.2
2-041	2541	93.6	2562	25.5

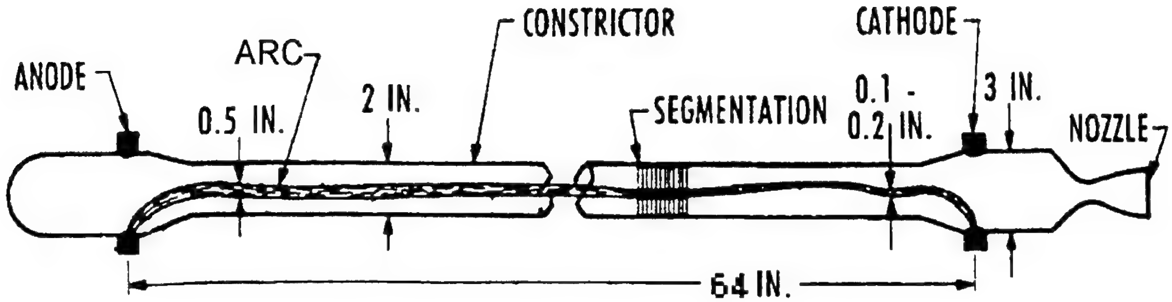
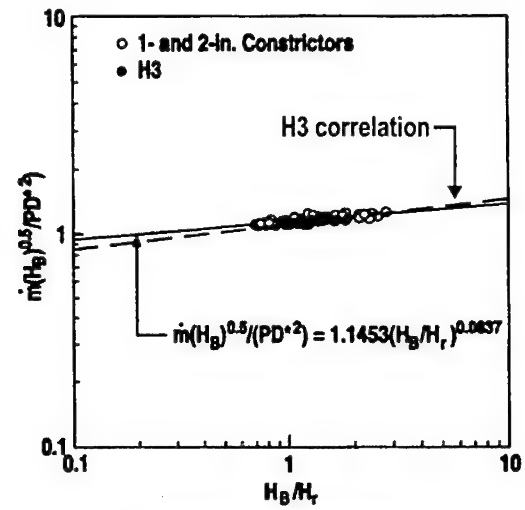
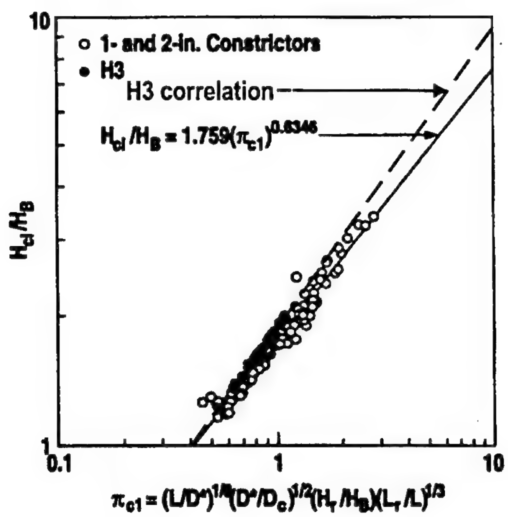


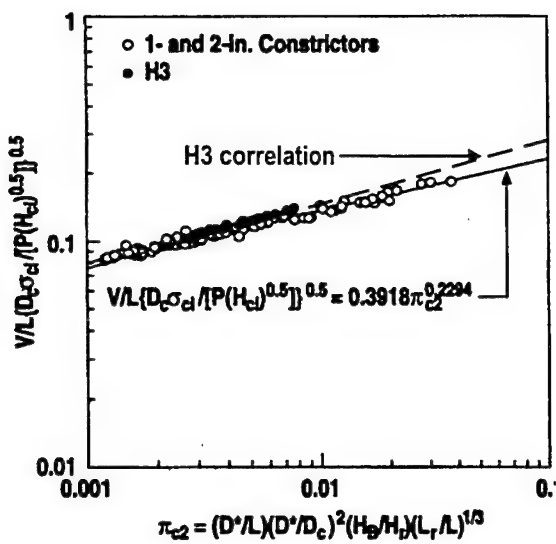
Figure 1. Configuration of typical high-pressure, high-power arc heater.



a. Mass flow parameter



b. Centerline enthalpy parameter



c. Voltage parameter

Figure 2 All data compared to correlations from 1 and 2 inch diameter constrictors and correlations from the H3 heater

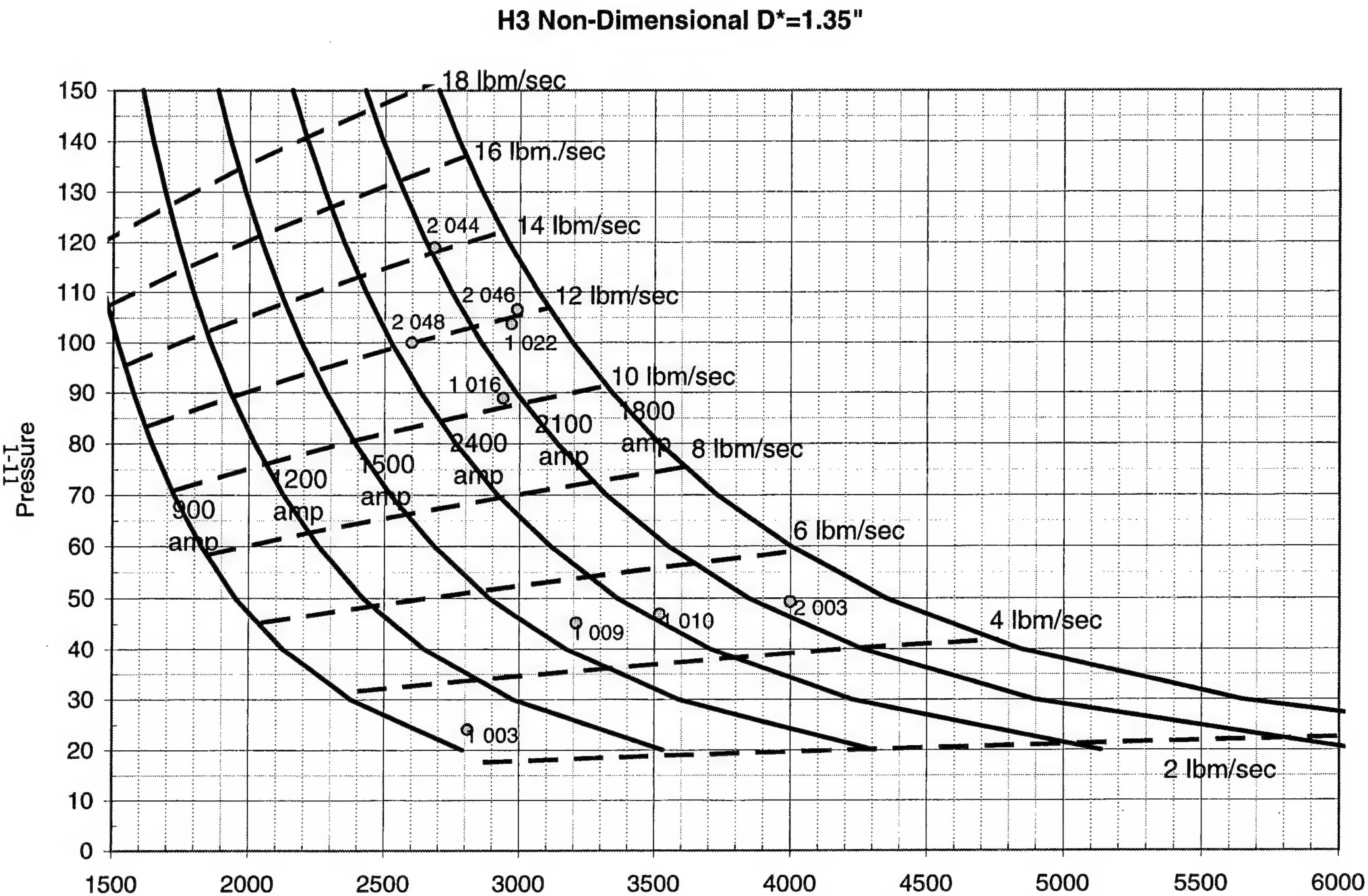


Figure 3 Operating maps for arc heater based on non-dimensional correlations of H3 data, D*=1.35 inches

a) Pressure vs. Enthalpy

H3 Non-Dimensional D*=1.35

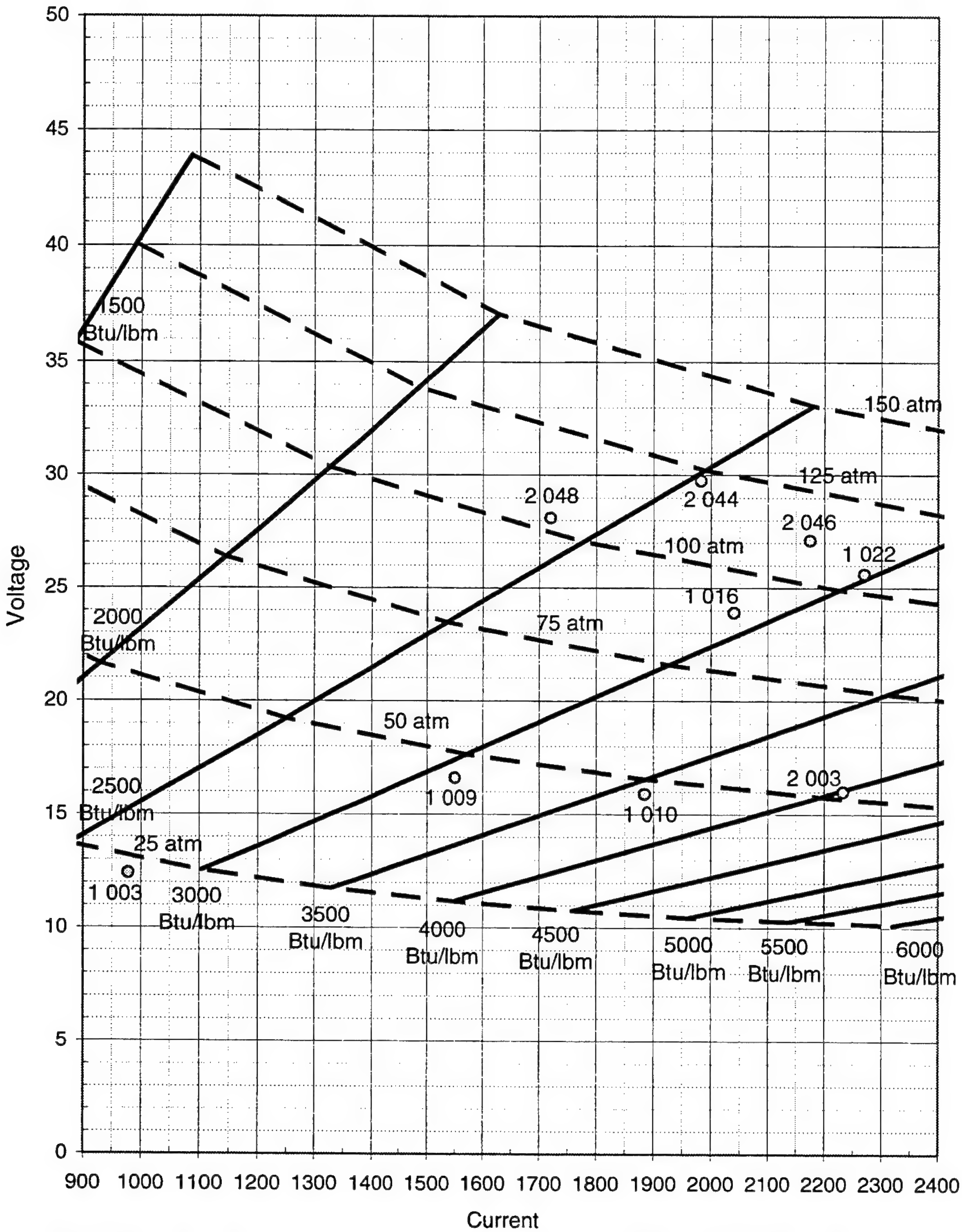


Figure 3 continued b) Voltage vs. Current

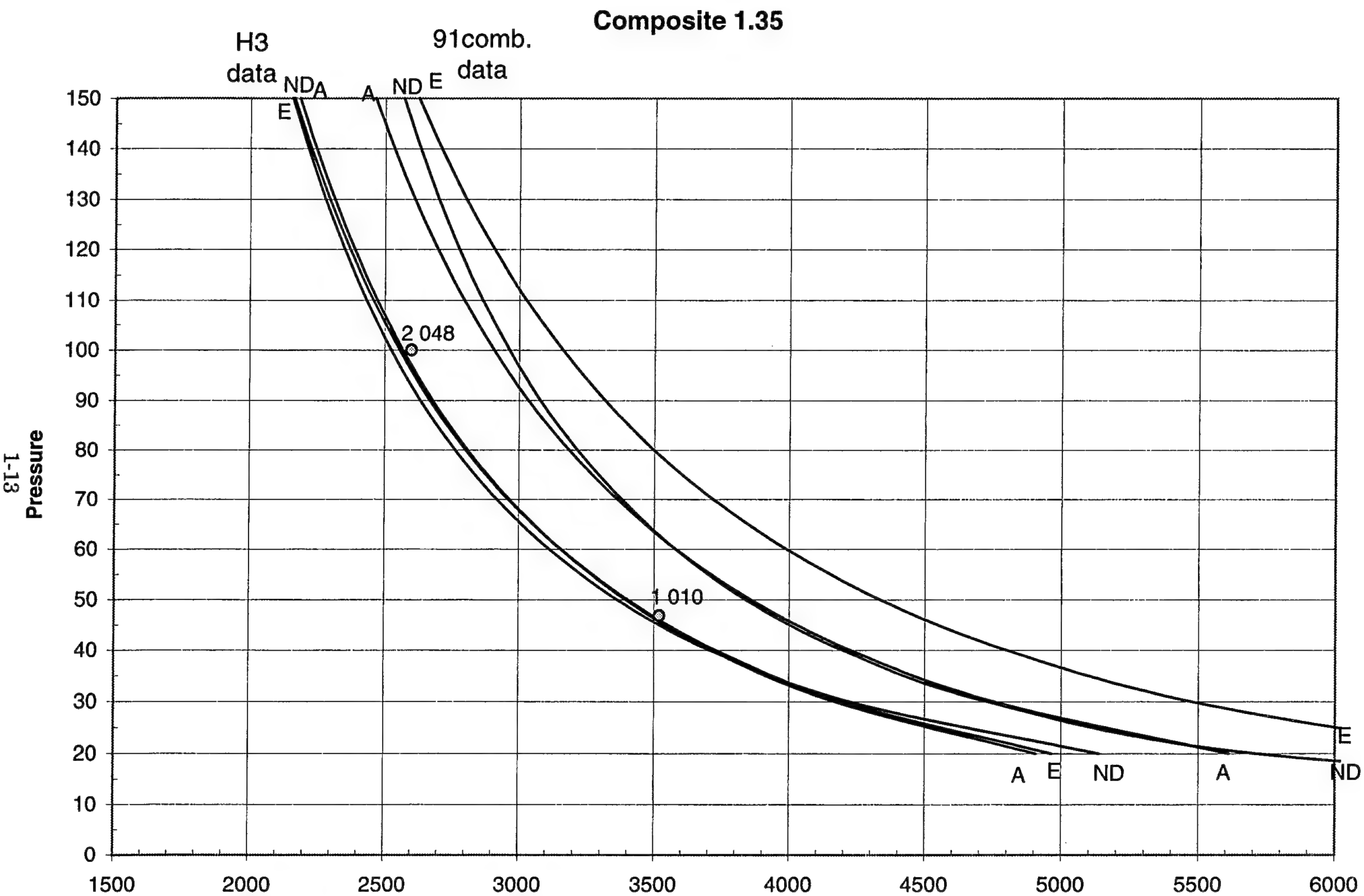
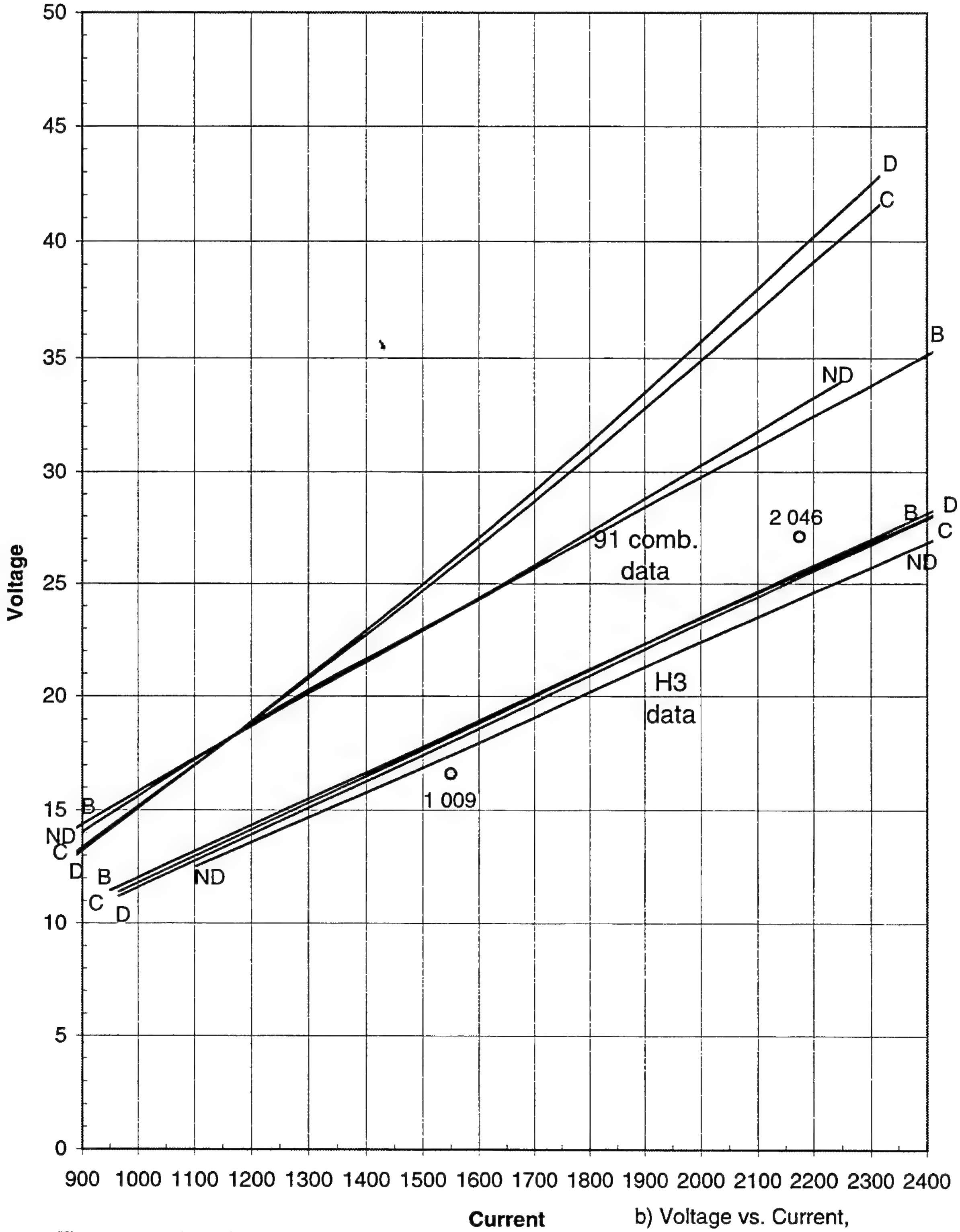


Figure 4 Comparison of various options for generating operating maps for the H3 heater, D*=1.35 inches

a) Pressure vs. Enthalpy, Current=1800 amps

1-13

Composite 1.35



b) Voltage vs. Current, Enthalpy=3000 Btu/lbm

Figure 4 continued

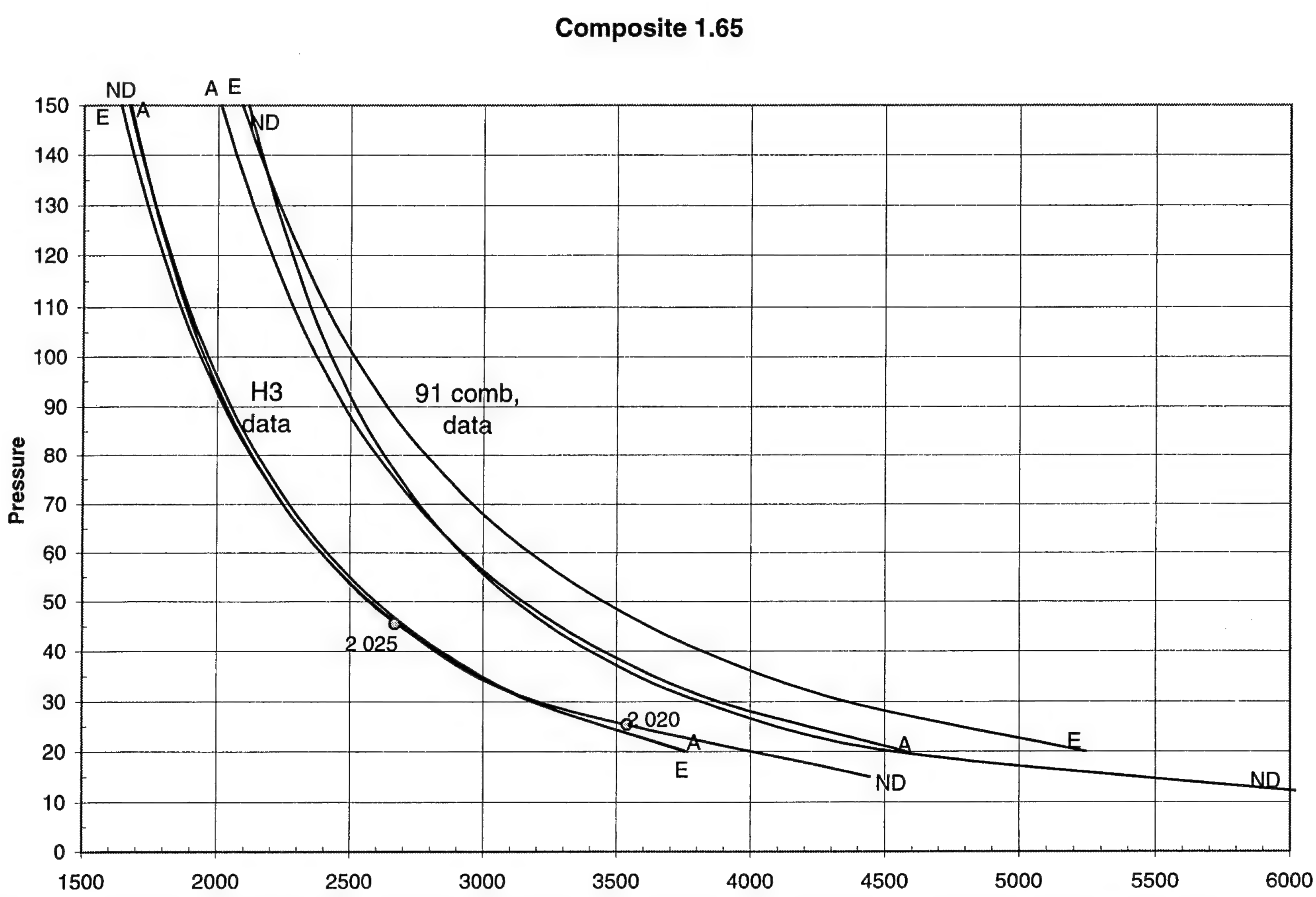


Figure 5 Comparison of various options for tenerating operating maps for the H3 arc heater, D*=1.65 inches

a) Pressure vs. Enthalpy, Current=1800 amps

Composite 1.65

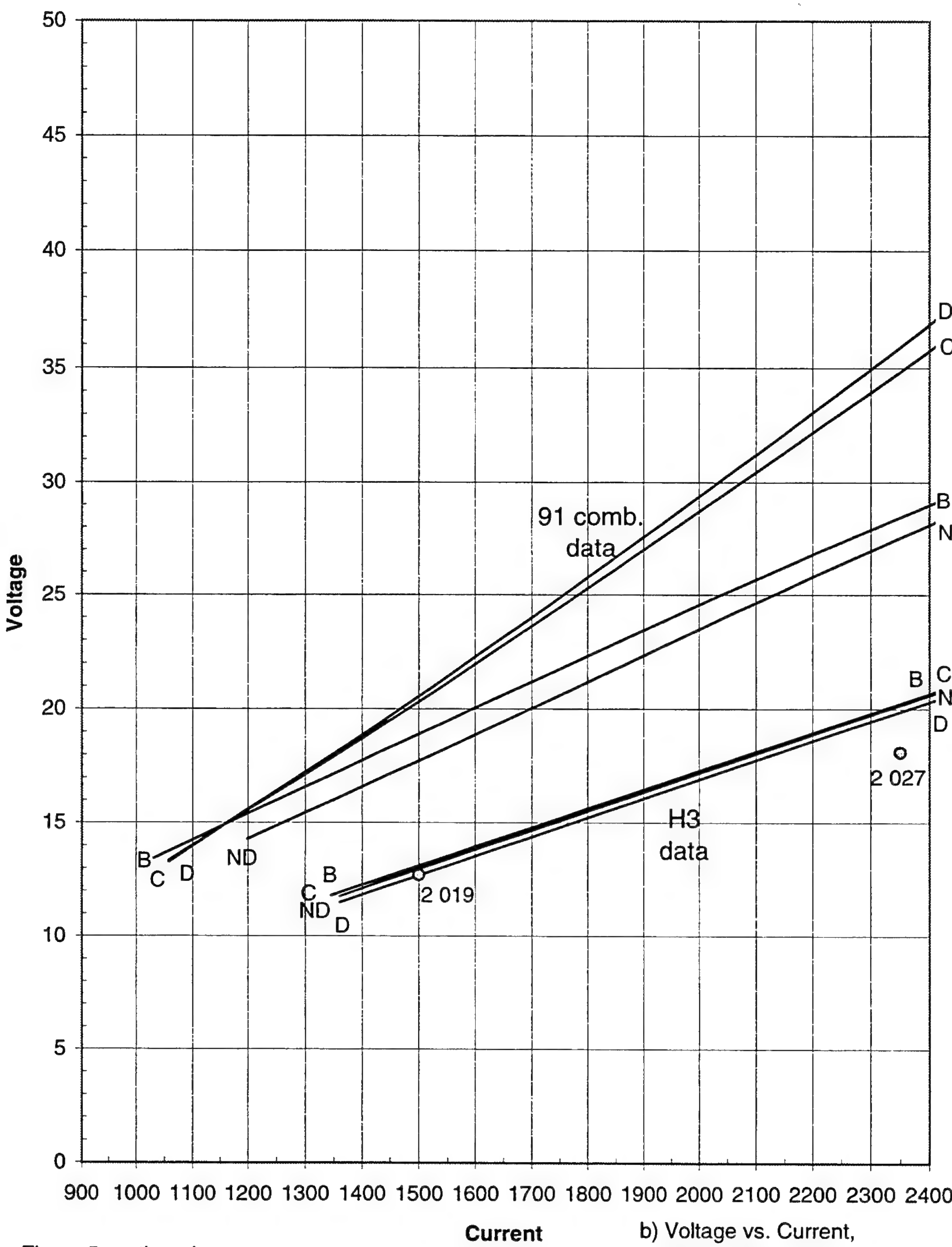


Figure 5 continued

b) Voltage vs. Current, Enthalpy=3000 Btu/lbm

Environmental Aspects in an Industrial Setting

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Final Report for:
High School Apprentice Program
Arnold Engineering and Development Center

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August 1996

Environmental Aspects in an Industrial Setting

Erica D. Brandon
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Abstract

During my apprenticeship at Arnold Engineering and Development Center my primary work assignment was in the Test and Facilities Support Department of Sverdrup Technology Incorporated. Working with environmental and manufacturing engineers in the machine and fabrication facility (Model Shop) my duties included studies, analysis and audits of environmental issues that impact this industrial facility. I received various projects, each helping me become familiar with various aspect of the environmental requirements associated with a machine shop.

Environmental Aspects in an Industrial Setting

Erica D. Brandon

Introduction

Over the past twenty years several dramatic changes have taken place in industry due to an increasing need to conserve our environment. Environmental impact laws have given new regulations and standards that must be met by all. Because of past mistakes our natural world has been saturated by toxins and pollutants, but in recent years these errors have been realized and now a conscious effort is being made to prevent further permanent damage. As a result of impacts to the environment more time, money, and energy must be dedicated to meet environmental regulations in industry.

Methodology

At the beginning of my apprenticeship at Arnold Air Force base contact was made with many environmental and manufacturing engineers of Sverdrup Technology Incorporated. From them I received many environmental projects with which I could help. With each project I became familiar with a different aspect of the various environmental regulations associated with a machine shop. I inventoried existing Material Safety Data Sheets (MSDS) against current chemical inventory, gathered

information on the status of environmental projects taking place in the Model Shop, assisted with a cutting insert salvage study and conducted my own environmental inspections of the Model Shop.

Results

My first project involved reviewing the Material Safety Data Sheets against the current chemical inventory. Every consumable product used in the Model Shop is required by law to have an MSDS available. An MSDS tells about the hazards of the material, proper storage and usage, what to do in case of skin or eye contact and how the material should be dealt with in the case of a spill. I took inventory of the 12 storage cabinets that contained flammable or acidic materials and compared my findings to the master MSDS list. There was a total of 361 products on the MSDS list from the previous year. Of these 361 products 116 were matched and 245 were not. The reason for this discrepancy is that some of the unfound items were replaced with 86 similar items from a different manufacturer. Since the products are so similar many times they are over looked when requesting new MSDSs from a manufacturer. Despite the similarities of the products, each product must have a MSDS. Including the 86 replacement items, the total products inventoried now equals 202 with only 159 products on the list that were not found in the shop. These 159 could be products that were phased out of use or just simply found to be unneeded.

For my second project I gathered information on the various environmental projects in the

Model Shop. These included; filtering system for acid cleaning vats, substitute for anodizing die, shut-off valves for anodizing tanks, machine cutting oil recycling unit and the purchase of a Trichlorotrifluorethane (Freon 113) recycling unit. The purpose of these environmental projects is to reduce the amount of waste generated from the model shop. The Model Shop is responsible for ten (10) active waste streams at AEDC.The following is a synopsis of the five projects:

1. One of the areas of the Model Shop is the acid cleaning area. Here two types of acid solution, nitric hydrofluoric and phosphoric, are used to de-grease metal parts and remove contaminants. Presently the acid vats are changed as needed, typically once a year. When the acid solution becomes contaminated and loses its effectiveness. The disposal of the "spent" solution creates two waste streams (number 23 & number 24). With the use of a recycling unit the life of the acid solutions can be doubled which would result in a fifty percent waste reduction. This project is on-going.

2. Another routine process conducted in the Model Shop is anodizing of metal parts. Parts are fabricated and coated per customer specification. Take for example a component produced for the ELA customer. Some of the internal chamber parts for ELA require a deep black anodizing due to heat and radiation transfer requirements. Presently the anodizing dye Sandal Fast Black is used. This dye contains chromium, which results in a hazardous anodizing and waste stream number 43. A substitute, Sandal Fast Black, is being evaluated for use. Due to the difference in resulting color spectrums Sandal Fast Black has to be thoroughly evaluated to assure that it is suitable

for use. If it is found acceptable waste stream number 43 will be eliminated since Sandal Fast Black is chromium free. Testing is being done.

3. Sometimes while filling the anodizing tanks personnel will leave the area which could result in an over flow. As a preventative measure, float shut-off valves are being installed to eliminate the potential for a spill.

4. Several of the machines in the Model Shop area use cutting oils as a coolant, which has to be changed when it becomes contaminated with metal chips and filings (waste stream number 94). Also when a machine is not in use for extended periods of time the coolant in it remains dormant and "sours" resulting in more waste. A recycling unit (Coolant Wizard) was purchased and is used to separate the oil from the waste which will increase the coolant's life span. This unit can also be used to agitate stagnate coolant oils, which will prevent cutting oil bacteria growth and agian minimize waste disposal. With this process the waste generated due to cutting oils can be cut by fifty percent. This unit will also eliminate waste stream number 94 since the small amount of remaining waste (metal chips and filings) can be packaged for disposal. The coolant wizard has been in use since 11 July with excellent results.

5. There are also machines in the Model Shop that use Trichlorotrifluorethane (Freon-113) to cool machines during operation. Since Freon-113 is an ozone depleting chemical (ODC) its availability is limited and its cost is increasing. The Freon recycling unit will increase the life of the existing Freon-113 and help conserve present supplies. The unit has been purchased and is expected to be implemented in August.

My third project consisted of evaluating and inventorying cutting tool inserts. Some machine inserts had become outdated and unuseful. Following the environmental regulations for disposal of these inserts, I sorted, counted, and listed these materials, in preparation for salvage.

The last project I completed was making my own environmental inspection of the Model Shop. An inspection usually consists of a general overview of work areas, checking of hazardous materials storage cabinets and a more detailed look at areas that have been a problem in the past. Records of past inspections are kept on hand as reference material and as a guide for which areas need the most work. I completed two environmental inspections, turning in my findings to the shop supervisors and members of Sverdrup's Environmental Team. On my first inspection I found four (4) discrepancies, the most critical one being a coolant leak in the fluid eliminator area of the shop. Two days after submitting the findings I made a follow up inspection. All the discrepancies that I noted had been corrected. My second environmental inspection of the Model Shop found that there were no discrepancies.

Conclusion

As a result of my apprenticeship with Sverdrup at Arnold Engineering and Development Center I have gained invaluable experience with what is a possible career choice for me. The machine and fabrication facility provided an ideal work

area where I was exposed to numerous environmental issues in an application oriented environment. The people of Sverdrup are working hard to keep ahead of the environmental requirements regulating industry. Most of the projects mentioned above are continuos and must constantly be updated. The changes taking place in the Model Shop can also be used as a mirror of changes taking place in all industrial settings in the United States. The modifications taking place are slow but sure. The industries realize that they can no longer afford, neither financially nor morally, to continue using materials that have been proven harmful to our environment.

A PROGRAM TO DETERMINE STATIC FORCE AND MOMENT FORCE BALANCE CALCULATIONS

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Final Report for:
High School Apprenticeship Program
Arnold Engineering Development Center

Sponsored By:
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August 1995

PROGRAM TO DETERMINE STATIC FORCE AND MOMENT BALANCE CALCULATIONS

Phillip A. Chockley III
Shelbyville Central High School

Abstract

Both hypersonic and supersonic ground tests were studied. Testing involves placing scaled down aircraft such as space shuttles or missiles in a wind tunnel. Inside the tunnel, air is blown over the model at speeds ranging from Mach 1.5 to Mach 10. While wind is blowing, the model can be moved to many different positions which create different aerodynamic forces and moments. These forces and moments are measured by a balance located inside the model. The balance measures the forces and moments by monitoring changes in resistivity in the balance circuit and recording the change in electrical current which is converted in a term called raw counts (1638.4 counts per volt). Raw counts are converted into workable numbers in which, among other things, static force and moment calculations come from. These calculations are put into a Sixth Degree of Freedom (6DOF) database by the user to determine the stability and control characteristics of the test article.

The purpose of this work was to develop an Excel formatted spreadsheet that permits raw balance data to be converted to engineering units. The primary use of the spreadsheet is to perform much more easily program checks for the static stability engineer to ensure programs developed for force and moment data are correct. The format permits easy input and output information on force balance to be readily checked . The program uses matrix inversion to convert raw data to engineering units and then transform coefficient form in a variety of axis systems.

PROGRAM TO DETERMINE STATIC FORCE AND MOMENT BALANCE CALCULATIONS

Engineers must convert "raw" force balance outputs to engineering units. Due to the complexity of the balance program data reduction, this is normally accomplished on a large mainframe computer. Engineers need an efficient way to perform check to ensure the main frame program is functioning correctly. This report outlines a method of accomplishing this for the engineer in an efficient and accurate way using the personal computer and an Excel spreadsheet. The following is a review of basic balance reduction methodology. Nomenclature is standardized and is defined in Reference 1. Sample results are presented in Figures 1-3.

Aircraft and missile designs must first be tested in the form of a scaled down model in wind tunnels. One of the main purposes for running wind tunnel tests is to help engineers determine the stability and control of aircraft and missiles. The stability and control of a vehicle is determined from the aerodynamic forces and moments imposed on a vehicle at various flight attitudes. These forces and moments are measured by mounting a balance inside of a model that represents the actual flight vehicle and recording the balance measurements for predetermined flight attitudes.

The balance in the model measures six components. These components consist of two pitching moments, two yawing moments, a rolling moment, and a drag force. These components not only measure the force and moments resulting from aerodynamic loads, they also measure the forces and moments resulting from the model weight and it center of gravity. For the end user to determine the stability and control of the vehicle tested, the forces and moments resulting from the model weight and its center of gravity must be removed. The six balance components must be reduced into usable terms that can be used to determine the stability and control of a vehicle.

Changes in balance resistive are converted into forces and moments by multiplying the change in each balance gage resistive by a calibration value. Fig. 1 defines input requirements. These results are called balance components (BCn). The following is a definition for each BCn value (See Fig 2):

BC1 - Pitching moment at x1
BC2 - Pitching moment at x2
BC3 - Yawing moment at x1
BC4 - Yawing moment at x2
BC5 - Rolling moment about balance center line
BC6 - Drag force

Each BC term includes aerodynamic forces and moments, as well as forces and moments created by the model and its center of gravity in relation to x1. These balance components are then used to calculate what is known as double prime terms. Double prime components consist of forces and moments relative to x1 in the balance axis.

The normal force double prime term (FN") is calculated by subtracting the moment measured at x2 (BC2) from the moment measured at x1 (BC1) which act in the in the x-z axis system, then dividing by the distance between x1 and x2. The equation used to define this term is:

FN"= (BC2-BC1)/(x1-x2)

The pitching moment double prime term (MM”) is located a x1 and is equal to the BC1 term. By once again subtracting the moment measured at x2 (BC4) from the moment measured at x1 (BC3), then dividing by the distance between x1 and x2, the side force (FY”) can be calculated. The only difference, however, between normal and side force is that normal force is measured in the x-z axis system, while side force is measured in the x-y axis system. The equation for side force is:

FY”=(BC4-BC3)/(x1-x2)

BC3 not only helps calculate FY”, but also completely defines yawing moment(MN”). The final two BC terms, BC5 and BC6, are equal to rolling moment(ML”) and drag force(FA”), respectively (See Fig. 2 for sample output results).

Once the double prime terms are found, the next step toward determining the aerodynamic loads is to calculate what is known as single prime terms. Single prime terms only include the forces and moments resulting from aerodynamic affects. Therefore, forces and moments resulting from model weight and it’s center of gravity must be removed. To accomplish this, several equations are used, in which three new terms are introduced: d, e, and f. These are trigonometric functions used to remove the model weight and it’s respective moment acting at x1. Their values are calculated through a matrices operation using several variable angles and explained as weight vectors along each axis. Once calculated, these values are used in conjunction with double prime terms, model weight (W), and the model center of gravity in relation to x1 to attain the single primes. In the case of normal force, the model weight is multiplied by the weight vector along the z axis (f), then added to the double prime term. The following equation is used (Fig. 3):

FN’=FN”+Wf

The pitching moment equation, as well as other single prime moment equations, incorporates yet another set of variables: the x-bar , y-bar, and z-bar. It is the model’s center-of-gravity location relative to x1 in each respective axis. The pitching moment double prime term is added to the product of the model weight, the x-bar, and the weight vector along the z axis, and the product of the model weight, the z-bar, and the weight vector along the x axis is subtracted to calculate the pitching moment single prime value. The equation is:

MM’=MM”+Wxf-Wzd

Determining side and drag force is very similar to determining normal force. In each case the double prime term is used, as is model weight. In side force, model weight is multiplied by the weight vector along the y axis then subtracted from the double prime term, and in drag force, the model weight is multiplied by the weight vector along the x axis then added to the double prime term. Their equations are:

FY’=FY”-We
FA”=FA”+Wd

As in the forces, single prime moment equations are similar as well. Like pitching moment, combinations of model weight, weight vector, and center-of-gravity location is added and subtracted from the double prime term to find yawing and rolling moments. These are the equations:

MM'=MM"-Wxe+Wyd
MN'=MN"+Wze-Wyf

At this point the data is strictly in the balance axis system. In order for the end user to evaluate the aerodynamic data, the forces and moments in the balance axis system must be rotated into the model axis system. This is accomplished by knowing the pitch, roll, and yaw misalignment angles between the balance and model. The unprimed terms are calculated through yet another series of equations using a matrix operation that rotates the model's forces and moments into the model axis system. The resulting values are (Fig. 3):

FN = normal force in the model axis system

MM = pitching moment in the model axis system

FY = side force in the model axis system

MN = yawing moment in the model axis system

ML = rolling moment in the model axis system

FA = drag force in the model axis system

The last step in force and moment calculation is the nondimensionalization of the unprimed terms. This constitutes eliminating the units of a value, leaving only the coefficient. This is accomplished in forces by dividing the unprimed term by dynamic pressure and reference area. In moments, it is accomplished by dividing the unprimed term by dynamic pressure, reference area, and reference length. By nondimensionalizing the calculations it makes it possible for the user to compare the data to that collected by other wind tunnels, or upscale the data to the size of the full scale object.

If not for the precision used in calculating forces and moments during wind tunnel testing, aircraft today would not have the ability to perform as well as they do. Through a series of mathematical equations, raw data is transformed into information the user can work with. With the knowledge a user gains from the wind tunnel, he can make changes to correct design flaws prior to the actual vehicle being built.

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Inputs

Input the following:							
	Degrees						
Alpha-1I	[illegible]		BC1	[illegible]		Xt	[illegible]
Alpha-DO	[illegible]		BC2	[illegible]		Yt	[illegible]
Phi-1	[illegible]		BC3	[illegible]		Zt	[illegible]
Alpha-P1	[illegible]		BC4	[illegible]			
Alpha-2i	[illegible]		BC5	[illegible]		CAB	[illegible]
Yaw-P	[illegible]		BC6	[illegible]			
Alpha-P2	[illegible]		X1	[illegible]			
Phi-2	[illegible]		X2	[illegible]			
Alpha-P3	[illegible]		Model Weight	[illegible]			
Omega-B	[illegible]		X-bar	[illegible]			LEGEND
Alpha-D	[illegible]		Y-bar	[illegible]		Input	
Yaw-D	[illegible]		Z-bar	[illegible]		Output	
Phi-D	[illegible]					Pitch	
Eta	[illegible]		q-inf	[illegible]		Roll	
Theta	[illegible]		s	[illegible]		Yaw	
Omega	[illegible]		I1	[illegible]			
			I2	[illegible]			
Phi-01	[illegible]		I3	[illegible]			
Phi-02	[illegible]		Im	[illegible]			
			XMRP	[illegible]			

Figure I

" Primes

BC1	[redacted]		FN"	[redacted]
BC2	[redacted]		MM"	[redacted]
BC3	[redacted]		FY"	[redacted]
BC4	[redacted]		MN"	[redacted]
BC5	[redacted]		ML"	[redacted]
BC6	[redacted]		FA"	[redacted]
X1	[redacted]			
X2	[redacted]			

Figure 2

Outputs

A	[illegible]			Double Primes	Single Primes	Aerodynamic Loads
B	[illegible]		FN	[illegible]	[illegible]	[illegible]
C	[illegible]		MM	[illegible]	[illegible]	[illegible]
			FY	[illegible]	[illegible]	[illegible]
D	[illegible]		MN	[illegible]	[illegible]	[illegible]
E	[illegible]		ML	[illegible]	[illegible]	[illegible]
F	[illegible]		FA	[illegible]	[illegible]	[illegible]
U	[illegible]			Body Axis		Missle Axis
V	[illegible]		CN	[illegible]	CN'	[illegible]
W	[illegible]		CLM	[illegible]	CLM'	[illegible]
			CY	[illegible]	CY'	[illegible]
G	[illegible]		CLN	[illegible]	CLN'	[illegible]
H	[illegible]		CLL	[illegible]	CLL'	[illegible]
K	[illegible]		CA	[illegible]	CA'	[illegible]
			XCPN/L	[illegible]	NCP/lm	[illegible]
L	[illegible]		XCPY/L	[illegible]	YCP/lm	[illegible]
M	[illegible]				CAF	[illegible]
N	[illegible]					
				Stability		Missle Stability
P	[illegible]		CLMS	[illegible]	CLMms	[illegible]
Q	[illegible]		CYS	[illegible]	CYms	[illegible]
R	[illegible]		CLNS	[illegible]	CLNms	[illegible]
			CLLS	[illegible]	CLLms	[illegible]
			CA	[illegible]	CLms	[illegible]
			CLD'	[illegible]	CLDms	[illegible]
			(L/D)S	[illegible]	(L/D)ms	[illegible]
			CAF	[illegible]	CAF	[illegible]

Figure 3

STAGNATION PRESSURE LOSS IN ROCKET COMBUSTION CHAMBERS

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August 1996

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Abstract

Rocket performance computer models require combustion chamber stagnation pressure as an input. Typically, however, only injector face pressure is measured. Due to irreversibilities generated in the combustion process, the combustion chamber stagnation pressure is lower than the injector face pressure. Rocket combustion texts by Sutton and Hill & Peterson develop constant specific heat relations for the flow in rocket combustion chambers of various geometries. These constant specific heat relations include the calculation of stagnation pressure loss. The later versions of the NASA Chemical Equilibrium and Applications code include the options of computing combustion chamber flow in both infinite and finite area combustion chambers. In this report I solved the constant specific heat relations using Newton's method to determine the ratio of the combustion chamber stagnation pressure to the injector face pressure as a function of contraction ratio. This was done for various values of the ratio of specific heats. The NASA code was executed for seven different fuel/oxidizer combinations at four different injector face pressures and at three different mixture ratios. The equilibrium results were also plotted in the form of the ratio of the combustion chamber stagnation pressure to the injector face pressure as a function of contraction ratio. The pressure ratio for each fuel combination, pressure, and mixture ratio were practically indistinguishable for all the equilibrium calculations. Therefore, I curve fit the equilibrium results to arrive at an analytic expression for the pressure ratio as a function of contraction ratio regardless of fuel/oxidizer combination, mixture ratio, or pressure. The analytic expression is within $\pm 1\%$ of the equilibrium calculations for all contraction ratios and within $\pm 0.25\%$ for contractions ratios greater than two.

STAGNATION PRESSURE LOSS IN ROCKET COMBUSTION CHAMBERS

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Introduction

Rocket performance computer models require combustion chamber stagnation pressure as an input. Typically, however, only injector face pressure is measured. Due to irreversibilities generated in the combustion process, the combustion chamber stagnation pressure is lower than the injector face pressure. Rocket combustion texts by Sutton[1] and Hill & Peterson[2] develop constant specific heat relations for the flow in rocket combustion chambers of various geometries. These constant specific heat relations include the calculation of stagnation pressure loss. The later versions of the NASA Chemical Equilibrium and Applications code[3,4,5] include the option of computing combustion chamber flow in both infinite and finite area combustion chambers. In this report constant specific heat calculations for the stagnation pressure ratio are compared to chemical equilibrium calculations. A general curve fit is developed for the stagnation pressure ratio as a function of contraction ratio. This curve fit is valid for combustion gases regardless of fuel/oxidizer combination, mixture ratio, or pressure.

Acknowledgments

I would like to thank Robert S. Hiers III for his time, patience, encouragement, and help throughout the project, Martha Simmons for her assistance with the NASA Equilibrium Program, David Pruitt for his help and encouragement on this project, Karl Kneile for his assistance with the curve fit procedure, and the personnel of TS5 Advanced Missile Signature Center, EL3 Propulsion Diagnostics, and EL2 Propulsion Computational Technology Section for their encouragement and assistance on this project.

Methodology

Constant Specific Heat Calculations

Rocket performance computer models require combustion chamber stagnation pressure as an input. Typically, however, only injector face pressure is measured. Due to irreversibilities generated in the combustion process, the combustion chamber stagnation pressure is lower than the injector face pressure. Rocket combustion texts by Sutton and Hill & Peterson develop constant specific heat relations for the flow in rocket combustion chambers of various geometries. A schematic of an idealized liquid propellant combustor is shown in Figure 1. Hill & Peterson gives the equation for the ratio of the combustion chamber stagnation pressure (P_{02}) to the injector face pressure (P_{01}) as

$$\frac{P_{02}}{P_{01}} = \frac{1+\gamma M_1^2}{1+\gamma M_2^2}\left\{\frac{1+\left[(\gamma-1)/2\right]M_2^2}{1+\left[(\gamma-1)/2\right]M_1^2}\right\}^{\gamma/(\gamma-1)} \tag{1}$$

where M is Mach number and γ is the ratio of specific heats. At the injector the Mach number will be very low. Thus, assuming $M_1 \approx 0$, this equation becomes

$$\frac{P_{02}}{P_{01}} = \frac{\left\{1+\left[(\gamma-1)/2\right]M_2^2\right\}^{\gamma(\gamma-1)}}{1+\gamma M_2^2} \tag{2}$$

Assuming that the flow in the exhaust nozzle is isentropic, M_2 is determined by the area contraction ratio A_C/A^*, in accordance with the following equation:

$$\frac{A_c}{A^*} = \frac{1}{M_2}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M_2^2\right)\right]^{(\gamma+1)/2(\gamma-1)} \tag{3}$$

Equation (3) is a transcendental relation for M_2 as a function of A_C/A^* . This requires a numerical method to solve for M_2. I chose to use Newton's Method. Equation (3) can be put in the form of

$$g(M_2) = \frac{A_c}{A^*} - \frac{1}{M_2}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M_2^2\right)\right]^{(\gamma+1)/2(\gamma-1)} = 0 \quad (4)$$

The iterative equation for Newton's Method that finds the root of $g(M_2)$ is as follows:

$$M_{2_{i+1}} = M_{2_i} - \frac{g\left(M_{2_i}\right)}{\frac{\partial g}{\partial M_2}\left(M_{2_i}\right)} \quad (5)$$

where

$$\frac{\partial g}{\partial M_2} = \left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M_2^2\right)\right]^{\left(\frac{\gamma+1}{2(\gamma-1)}\right)-1} - \left\{\frac{1}{M_2^2}\left[\frac{2}{\gamma+1}\left(1+\frac{\gamma-1}{2}M_2^2\right)\right]^{\frac{\gamma+1}{2(\gamma-1)}}\right\} \quad (6)$$

Newton's Method was used to solve Equation (3) for M_2 as a function contraction ratio (A_C/A^*) for several values of γ. These values of M_2 were substituted into Equation (2) to arrive at the stagnation pressure ratio. The stagnation pressure ratio (P_{02}/P_{01}) is plotted as a function of contraction ratio (A_C/A^*) in Figure 2. Note that for large contraction ratios the stagnation pressure ratio approaches unity. Note also that the stagnation pressure ratio is a relatively weak function of γ.

Chemical Equilibrium Calculations

The later versions of the NASA Chemical Equilibrium and Applications code include the options of computing combustion chamber flow in both infinite and finite area combustion chambers. This corresponds to infinite and finite contraction ratio combustion chambers as defined by Hill & Peterson. The NASA Equilibrium code includes the effects of a varying γ because of chemical changes due to combustion. The model will compute the stagnation pressure at the contraction ratio given the fuel/oxidizer combination, mixture ratio, contraction ratio, and injector face stagnation pressure as input. The stagnation pressure ratio (P_{02}/P_{01}) can then be computed. The specific fuel/oxidizer combinations and mixture ratios used are shown in Table 1. Injector face stagnation pressures of 100, 500, 1000, and 5000 psia were used for each fuel/oxidizer combination at each mixture ratio.

Fuel/Oxidizer	Rich O/F	Nominal O/F	Lean O/F
H_2/O_2	**4.8**	**6.0**	**7.2**
RP-1/IRFNA	**2.88**	**3.6**	**4.32**
UDMH/IRFNA	**2.64**	**3.3**	**3.96**
RP-1/LOX	**1.92**	**2.4**	**2.88**
AZ-50/N_2O_4	**1.50**	**1.88**	**2.26**
MMH/N_2O_4	**1.28**	**1.6**	**1.92**
UDMH/N_2O_4	**1.68**	**2.1**	**2.52**

Table 1 Run Conditions for Equilibrium Stagnation Pressure Ratio Calculations

The stagnation pressure ratio as a function of contraction ratio for each fuel/oxidizer combination are shown in Figures 3-9: H_2/O_2, RP-1/IRFNA, UDMH/IRFNA, RP-1/LOX, AZ-50/N_2O_4, MMH/N_2O_4, UDMH/N_2O_4, respectively. Note that the lines on each figure are practically indistinguishable and that the figures are practically indistinguishable from each other. This indicates that the stagnation pressure ratio is practically independent of fuel/oxidizer combination, mixture ratio, and injector face stagnation pressure. To further demonstrate this, the maximum and minimum stagnation pressure ratio at each contraction ratio (regardless of fuel/oxidizer combination) is plotted in Figure 10. It is apparent from Figure 10 that the stagnation pressure ratio for typical liquid rocket engine combustion gases is practically a function of contraction ratio only. This suggests that a universal curve fit of stagnation pressure ratio as a function of contraction ratio should be attainable.

Curve Fit of Equilibrium Stagnation Pressure Ratio

The curve of stagnation pressure ratio versus contraction ratio asymptotes to unity at large contraction ratios. This indicates exponential behavior. Therefore, a curve fit of the form

$$\frac{P_{0_2}}{P_{0_1}} = 1.0 - e^{L_n\left(\frac{A_c}{A^*}\right)} \qquad (7)$$

was attempted, where L_n is some polynomial of order n in A_c/A^*. That is:

$$L_n\left(\frac{A_c}{A^*}\right) = \beta_0 + \beta_1\left(\frac{A_c}{A^*}\right) + \beta_2\left(\frac{A_c}{A^*}\right)^2 + \ldots + \beta_n\left(\frac{A_c}{A^*}\right)^n \qquad (8)$$

The coefficients (β_0, β_1, β_2,...β_n) of the exponential/polynomial fit were found by fitting all the equilibrium calculations using standard least squares fitting techniques[6] after first linearizing Equation (7) by taking the natural logarithm of both sides.

The results of second-, third-, and fourth-order fits along with the maximum and minimum data at each contraction ratio are shown in Figure 11. It is obvious that the fourth-order fit gives the best agreement, particularly at the lower contraction ratios. Figure 12 shows the percent error in the fourth-order curve fit when compared to both the maximum and minimum equilibrium data at each contraction ratio. The analytic curve fit is within ±1% of the equilibrium calculations for all contraction ratios and within ±0.25% for contractions ratios greater than two. Typical rocket combustors are designed with contraction ratios between 2 and 4. The coefficients for the second- , third-, and fourth-order curve fits are shown in Table 2.

Order	β_0	β_1	β_2	β_3	β_4
2	**-1.005**	**-1.059**	**5.618E-02**	**xxxxxxxxxx**	**xxxxxxxxxx**
3	**-0.3663**	**-1.621**	**0.1866**	**-8.345E-03**	**xxxxxxxxxx**
4	**0.4369**	**-2.580**	**5.363**	**-5.691E-02**	**2.250E-03**

Table 2 Coefficients for Curve Fit of Stagnation Pressure Ratio

Conclusions

The most important conclusion of this project is that stagnation pressure ratio is practically a function solely of contraction ratio for typical rocket combustion conditions. A universal curve fit was generated for stagnation pressure ratio as a function of contraction ratio. The analytic expression for the curve fit is within +/- 1% of the equilibrium calculations for all contraction ratios and within +/- 0.25% for contractions ratios greater than two. This will allow quick and accurate estimation of stagnation pressure losses in rocket combustion chambers in chemical equilibrium without doing chemical equilibrium calculations. Even constant specific heat calculations require numerical methods for solution. The curve fit developed here provides a closed form solution.

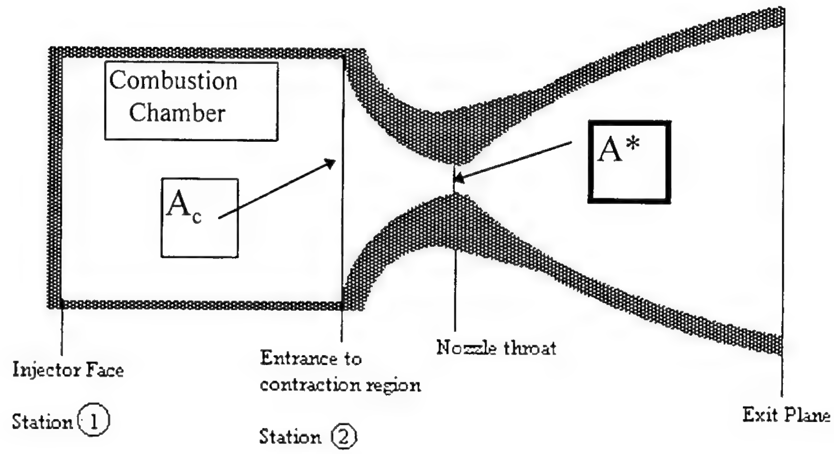

Figure 1 Schematic of Idealized Liquid Propellant Rocket Combustor

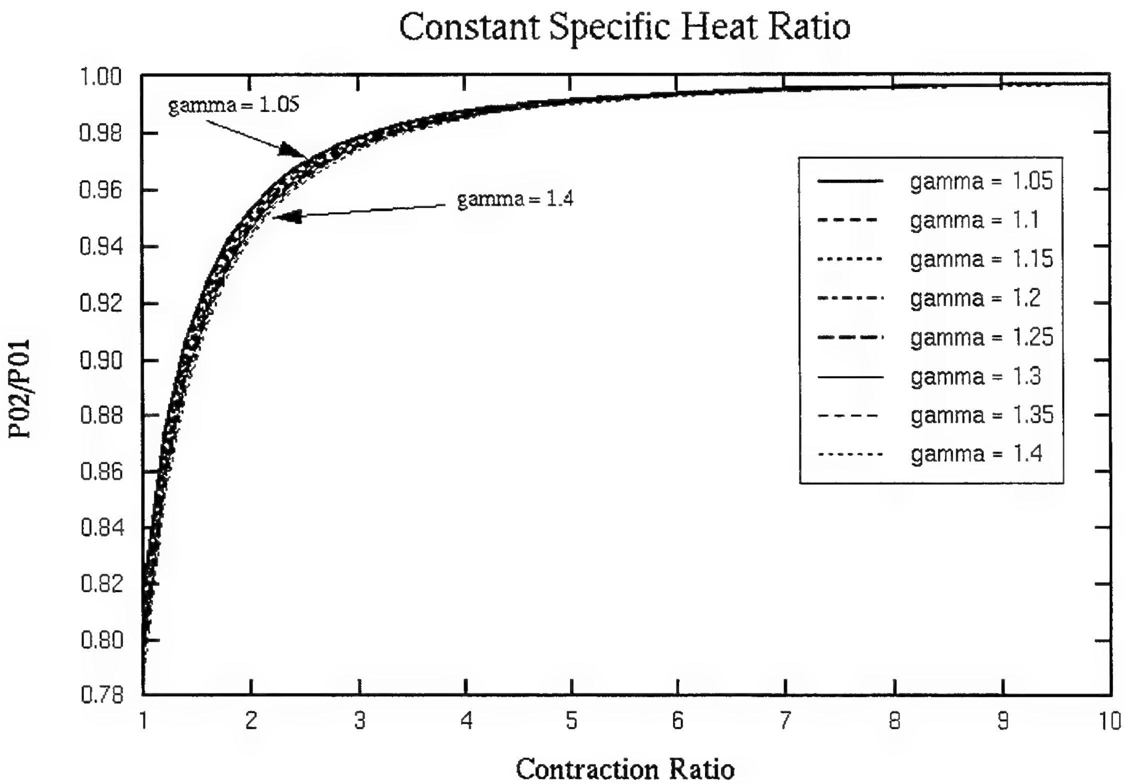

Figure 2 Constant Specific Heat Stagnation Pressure Ratio

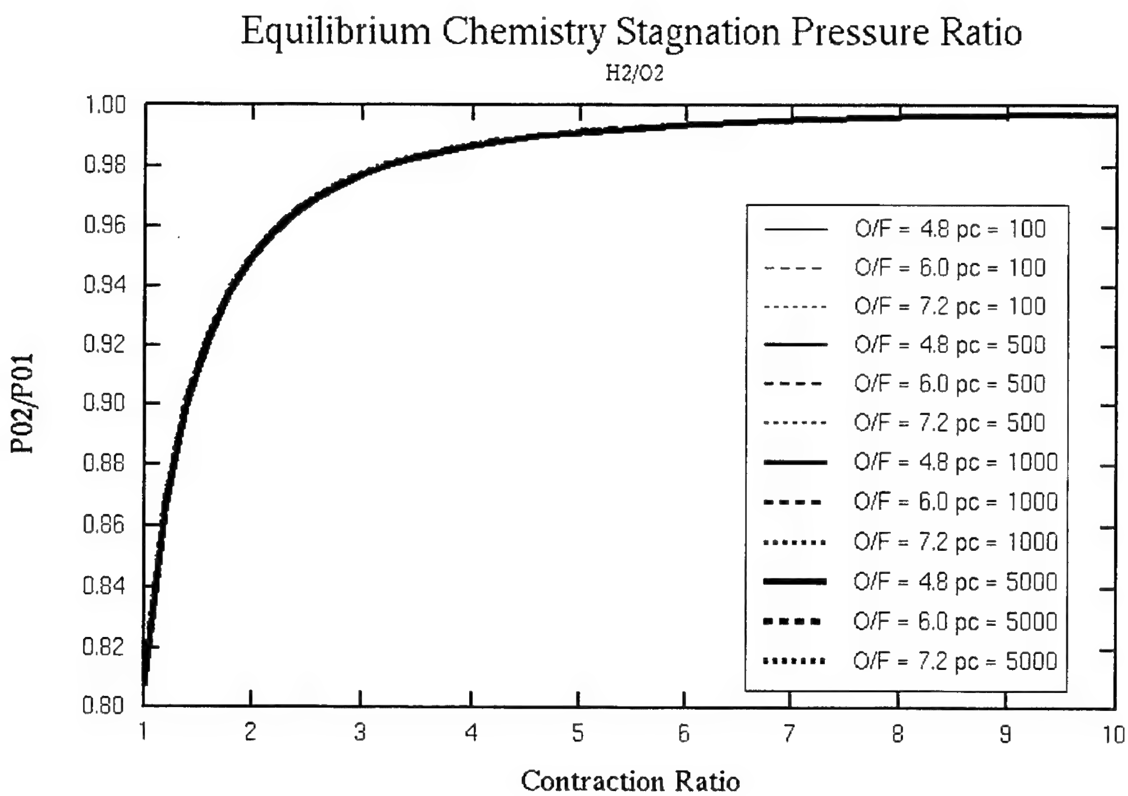

Figure 3 Equilibrium Stagnation Pressure Ratio for H_2/O_2

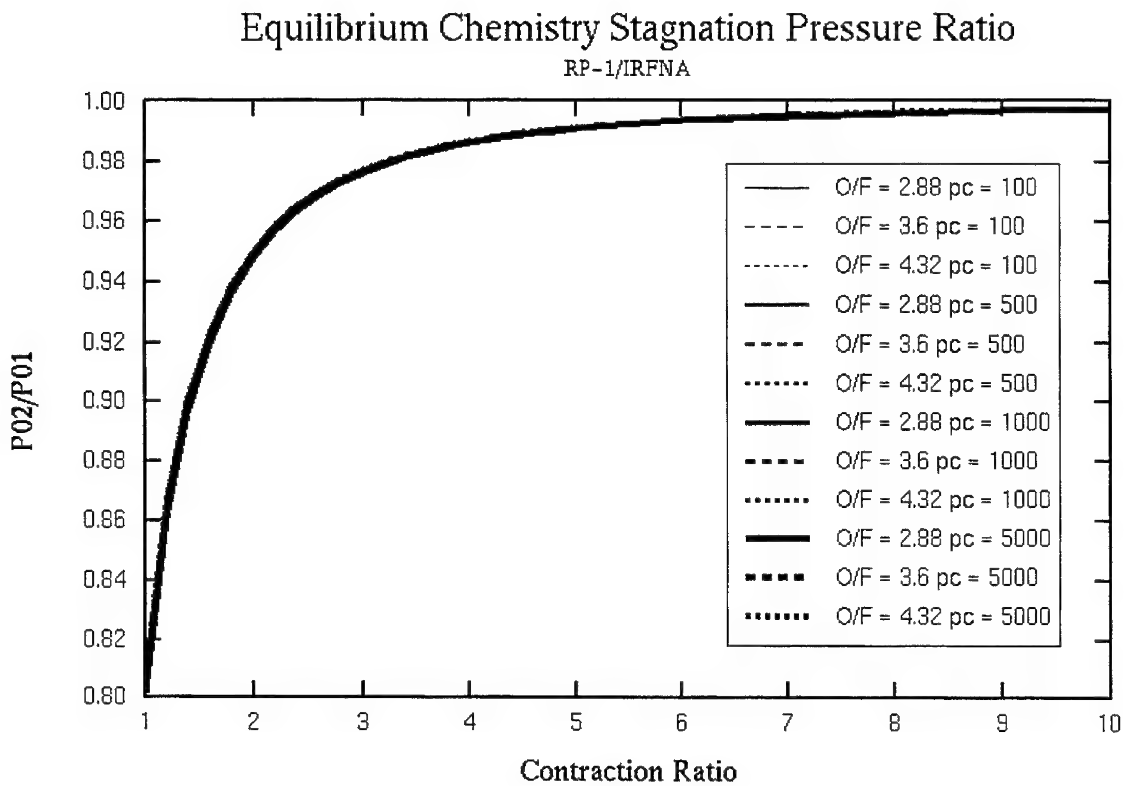

Figure 4 Equilibrium Stagnation Pressure Ratio for RP-1/IRFNA

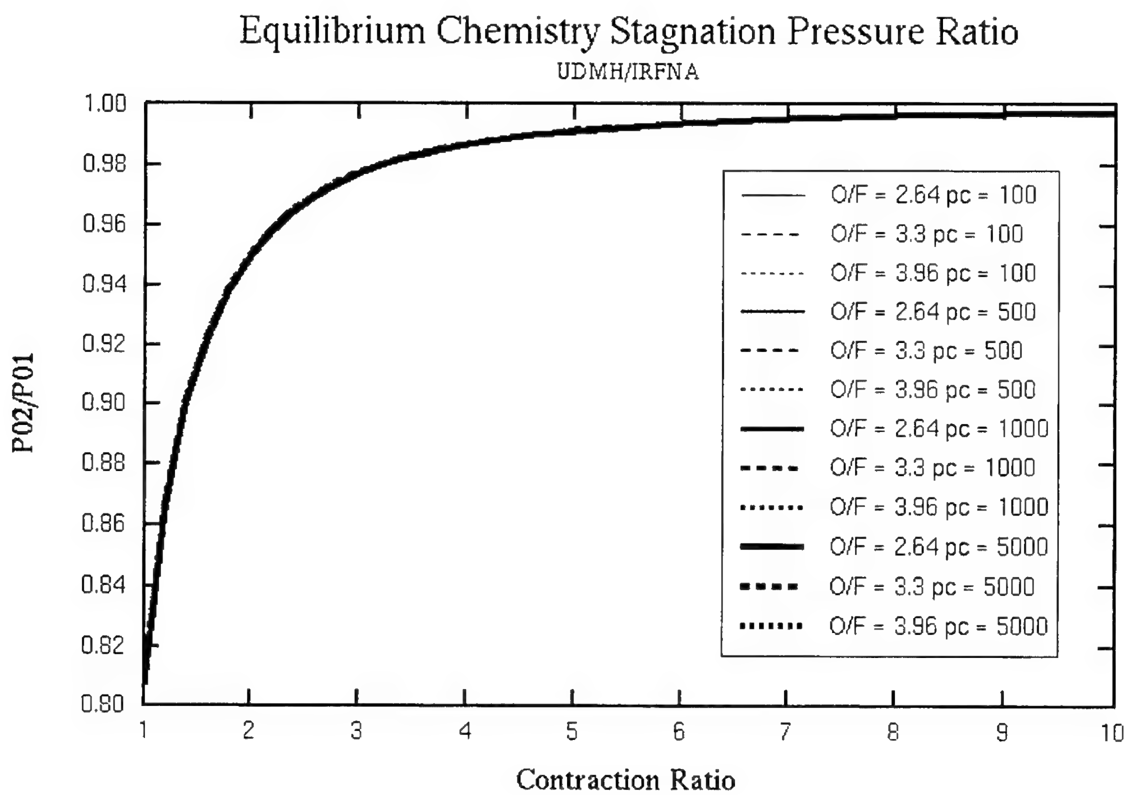

Figure 5 Equilibrium Stagnation Pressure Ratio for UDMH/IRFNA

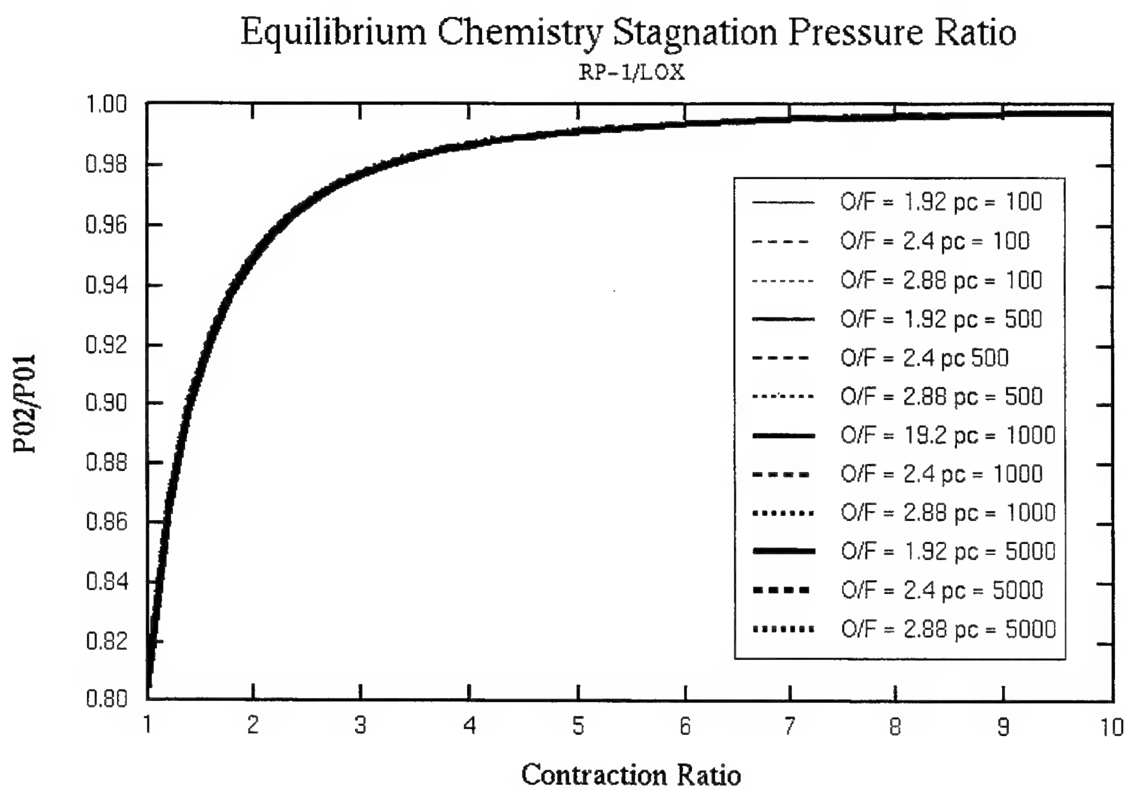

Figure 6 Equilibrium Stagnation Pressure Ratio for RP-1/LOX

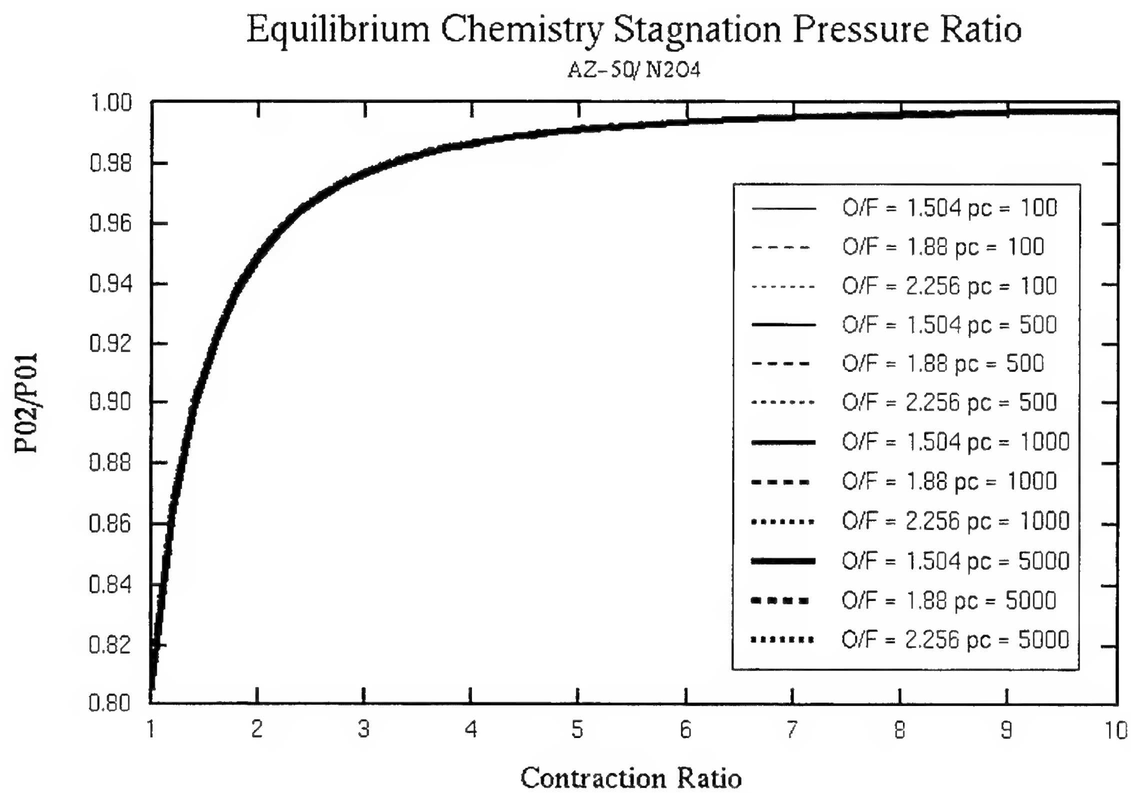

Figure 7 Equilibrium Stagnation Pressure Ratio for AZ-50/N_2O_4

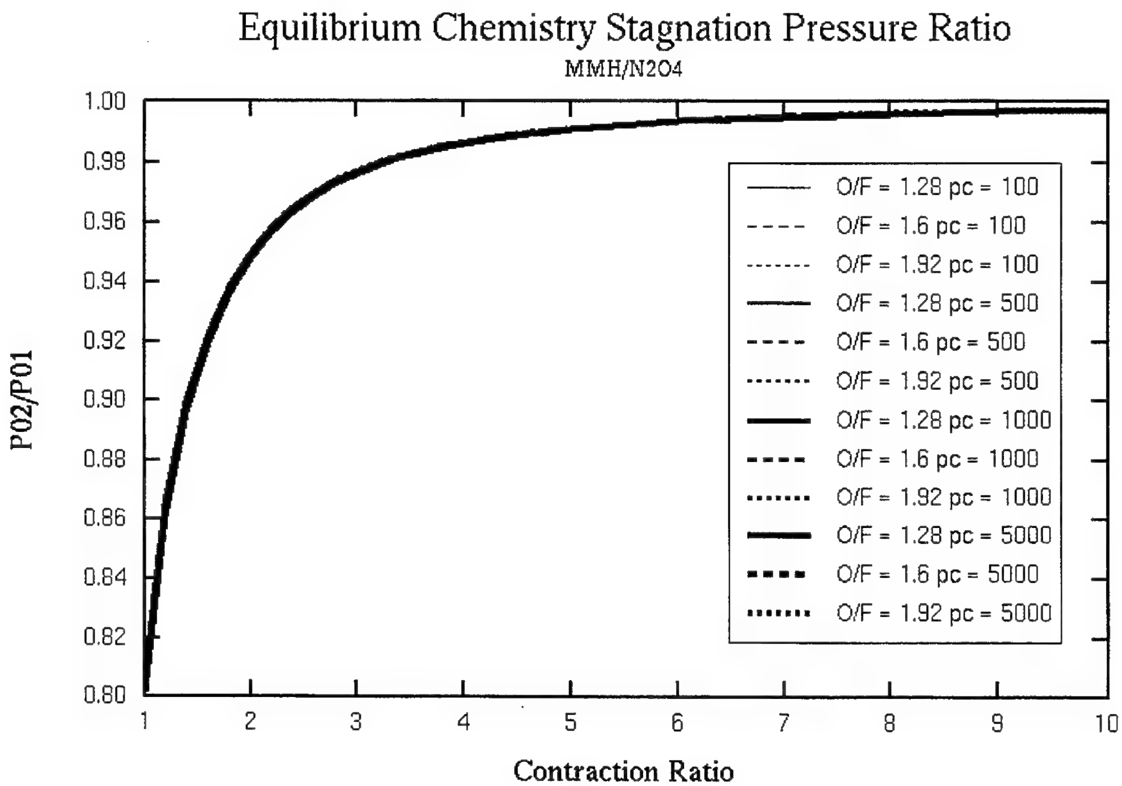

Figure 8 Equilibrium Stagnation Pressure Ratio for MMH/N_2O_4

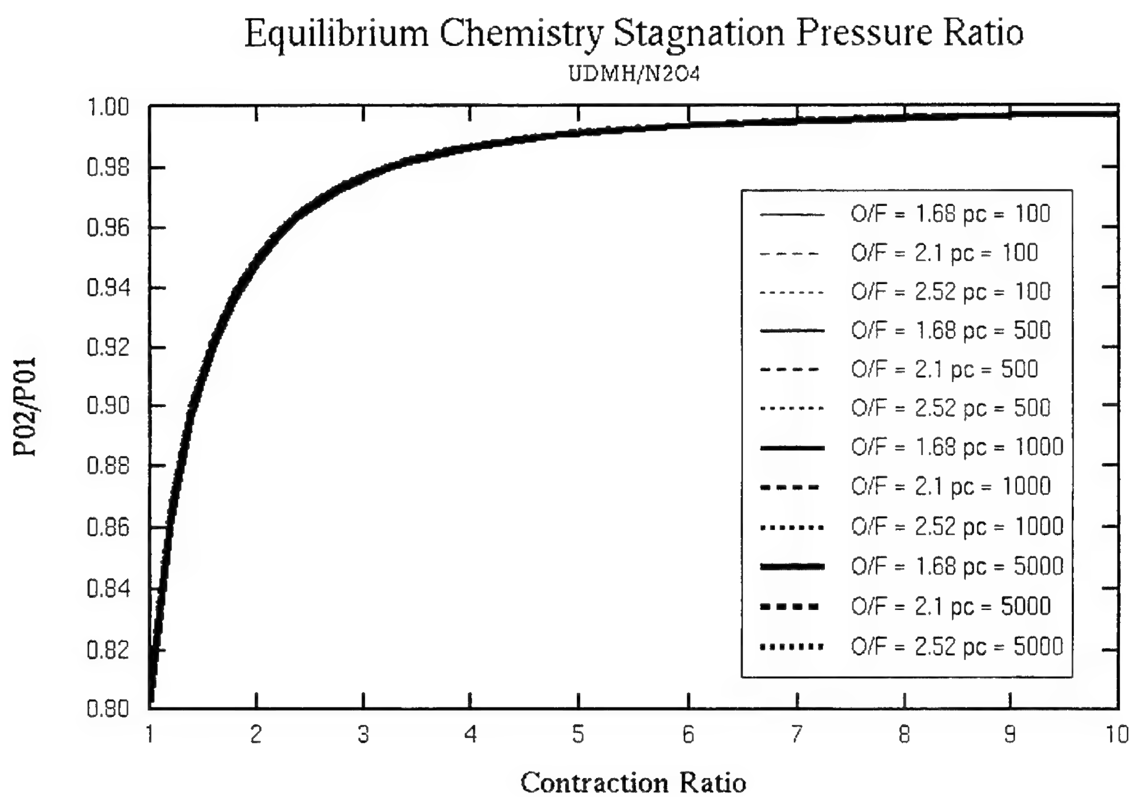

Figure 9 Equilibrium Stagnation Pressure Ratio for UDMH/N_2O_4

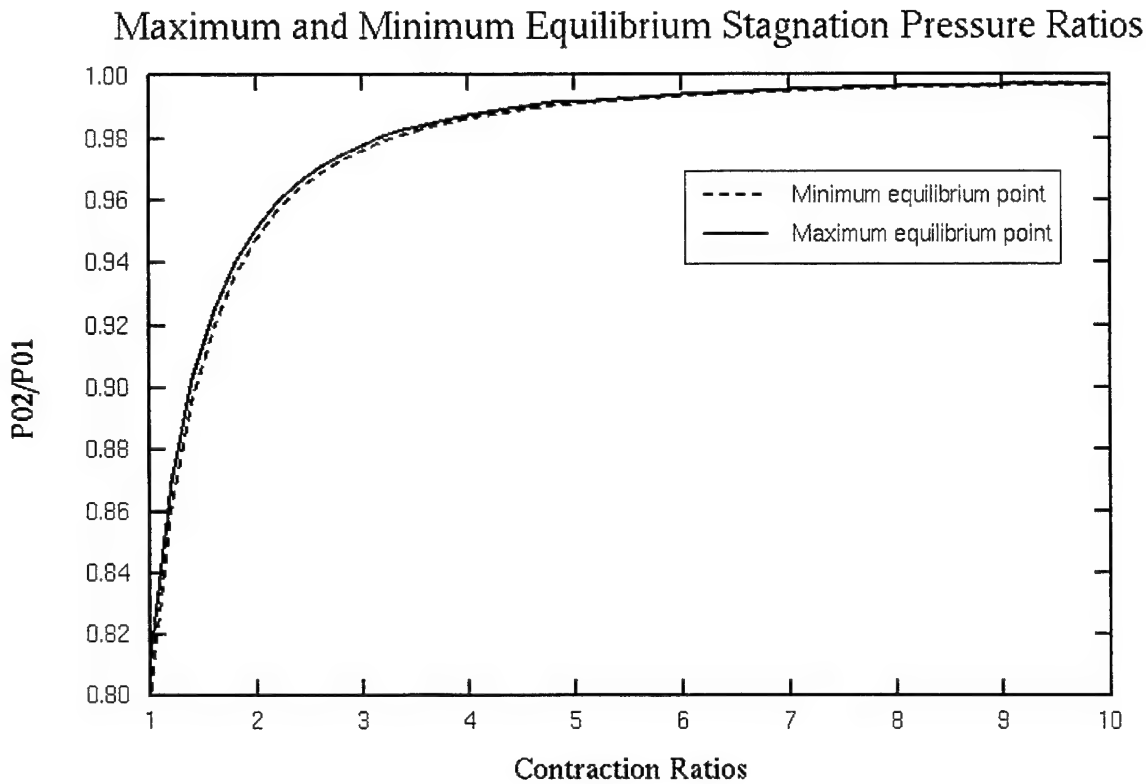

Figure 10 Maximum and Minimum Stagnation Pressure Ratio for all Equilibrium Chemistry Calculations

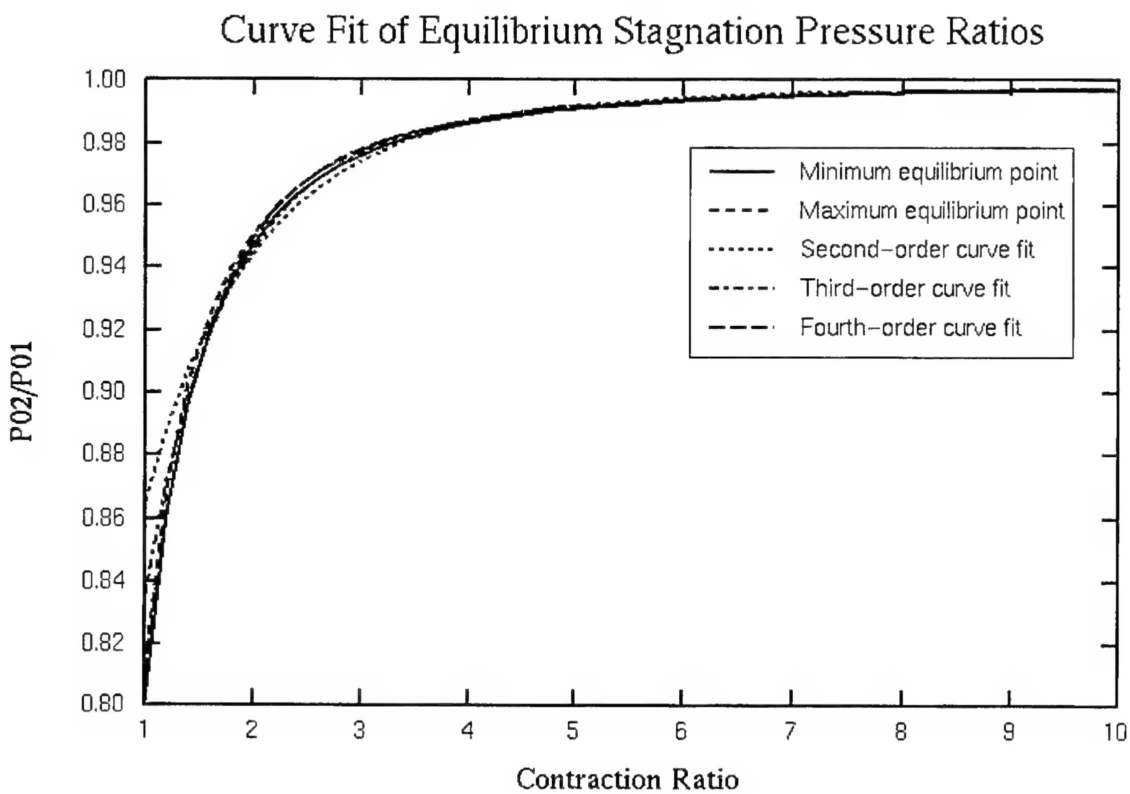

Figure 11 Exponential/Polynomial Curve Fit of Equilibrium Stagnation Pressure Ratio

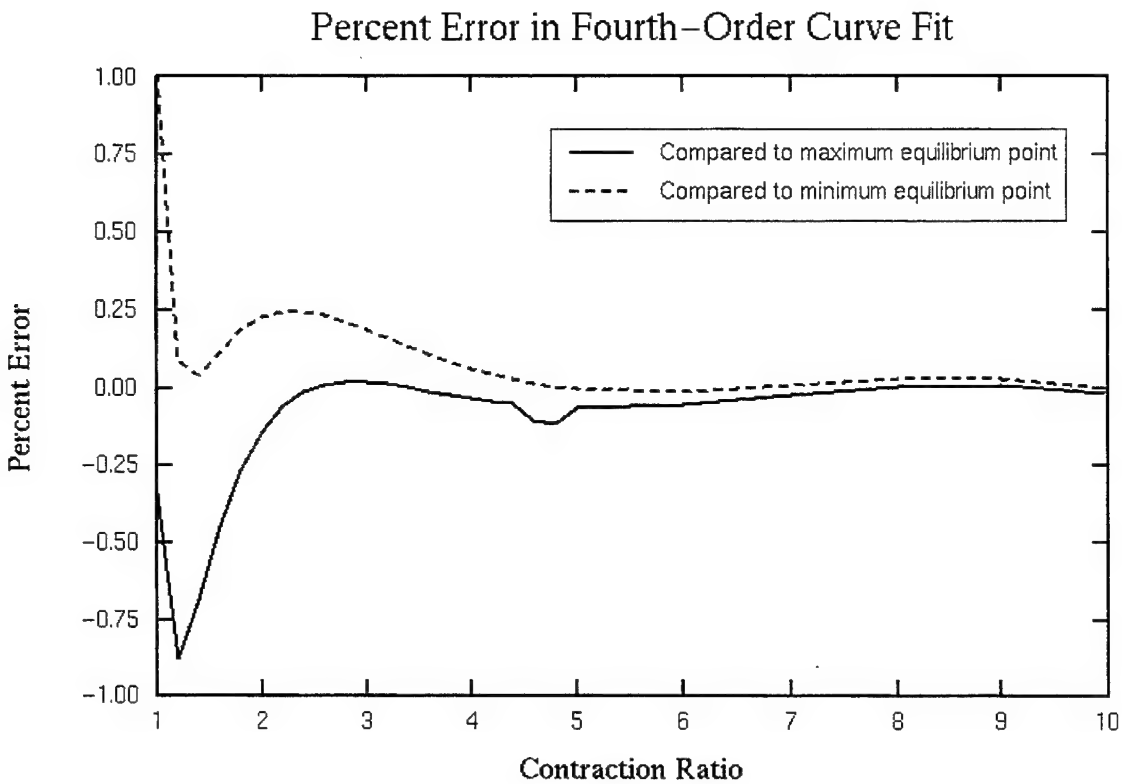

Figure 12 Potential Error in Fourth-Order Exponential/Polynomial Curve Fit

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Wesley A. Dixon's report was not available at the time of publication.

CONSTRUCTING AN INTERNET HOME PAGE USING HYPERTEXT MARKUP LANGUAGE

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Jason E. Hill
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Abstract

HyperText Markup Language (HTML) and the construction of a home page were studied. The home page was constructed for the Optical Diagnostics Self-Directed Team, an AEDC technology group. To construct the home page HTML was used as is standard in all present day websites. Many hours of research of HTML were done to learn the language in order to construct a well written and appealing home page. Then the actual home page was constructed, perfected, and updated through the remaining time period. The home page was designed to be informative, elegant, and resourceful in nature and it also performs the function of giving the team a sense of unity and identity.

CONSTRUCTING AN INTERNET HOME PAGE USING HYPERTEXT MARKUP LANGUAGE

Jason E. Hill

Introduction

Research and development, recently, have been accelerated by the use ever increasingly powerful computational and data storage equipment. The frontier of this new information age that is colloquially called the 'Net' (i.e., the Internet) is a new resource that can be tapped into. This home page project uses this resource in a functional way to convey information. Instead of the team spending valuable time and money on a printed newsletter, the same information and much more can be shown on a home page. All current Web pages are written in some form of HTML. This acronym means HyperText Markup Language. The 'Hyper ' is a computer jargon adjective that pertains to the Internet and sometimes specifically to the World Wide Web (from Greek meaning "over; above" connoting a sense of higher dimensions). "Text" is used because originally HTML could display text on pages and as a result these first sites were quite bland, but today the sky, no the stars are the limit. The way the display capabilities have evolved parallels the advances in the real-world medias, but at a much faster rate. For example, the first innovation, text, changed cyberspace as much as the printing press changed civilization. In a side note when HTML "documents" are displayed on a server it is called "publishing," just as books and magazines are. To break the monotony soon color came, and later photographic quality pictures, again paralleling media development. After the camera came the radio, and now sound is quite commonly used. Next the capability to display animations and silent movies was developed and most recently there is one site that can support movies with sound. The final two letters of the acronym describe the what it is and the way it is written and functions. HTML uses tags to separate the commands from the text to be displayed, like taping notes and pictures to a background then making a photocopy that is seamless. The system however is not as a newspaper's printing press in which the exact location and font of the text are defined, but instead offers a universal, for the computers, and logical, for the people, way to display the information. These are the primarily good qualities of HTML, but there are some drawbacks. These problems arise not from the language itself but because of the shear number of different servers and operational systems out today. There are no standard pixel or screen sizes, so the actual display differs

from machine to machine. Furthermore, there are various subversions of HTML. There are three major versions, the most recent being HTML 3.0, put out by its creator company CERN, and there are also several commands that are put out by and only work on specific browsers, such as Netscape 2.0, Microsoft Browser, etc. Because of this there is only a limited vocabulary that has universal recognition, that can be the biggest limitation for sites that want to be universal.

Methodology

The method of constructing a home page is by using HTML and other techniques. First, I had to learn HTML. Although I was computer literate, I had no experience in using the Internet or using HTML. Learning the Internet was not much of a problem and I soon found much information about HTML and constructing a home page on-line. Reading about how to do something is one thing but actually doing it is another. After acquiring an old computer and a web-page editor, which enables one to write or rewrite the HTML document then see the changes applied to page, I started to truly learn how to make a home page. The HTML document is the source of the information contained on a page and contains all of the HTML tags as well. I experimented and learned on my own this way and also looked at the source documents (unchangeable) of quality web-pages to get an idea of what a good home page appears. After many test pages and some ideas I could start the real work. There was a very out of date, but informative home page available pertaining to what the newly named team does on my mentor's computer. My computer was not cleared for Internet access so the files for the page had to be copied to my computer. Through the web-page editor I could view and change the page easily. First, I gave the page what I considered a better background color. Then, I did a major remodeling by adding tables, giving a sense on uniformity, and fitting more information on the scene yet allowing some space. Next, I made it much more ergonomical by providing links to the tops of long pages and other related pages to allow the user more freedom when on the page. After all that could be done was done the files were then copied back to their original home and the miscellaneous images and texts were reconnected. Since the texts were scanned in, they had to be proofread and corrected. Also the department had recently changed its name to Optical Diagnostics Team, so all of the titles and headings needed changing. An official AEDC shield GIF file was then inserted as background and many other

images were created or modified to serve the page. The texts and contacts were then expanded and updated. The last major revision was the greatest and most difficult. The older home page was made before even the base had page and focused heavily upon the technology and equipment involved in that field, which is now generally covered on the larger base page. It would have to pertain more to the people involved and the team itself to fulfill its function. This was accomplished by redoing the flow tree, adding an interactive roster and by listing the team's vision, goals, and motivations. The final form bared little resemblance to the original.

Results

Result of this project is a home page that is not only of good quality but is very useful as well. All a team member needs to do is to look at the page to find out the latest issues inside the team. Although I can not stay any longer the home page is not designed to be static, so I encourage the team to change it when needed. It was designed to be interactive and evolutionary not as a hardcopy book on a dusty shelf of a by-gone age still calling itself modern. The best way to explain the home page itself is to not try, but instead show it as it is. The next twelve pages show the Optical Diagnostics Home Page's major sites. First, is the main menu page, Fig. 1, that ties every other page together. The next three pages after that are about team information, including a list of officers, Fig. 2; a roster, Fig 3; and an official Vision/Mission/Goals statement, Fig 4. Then the next five pages, Figs. 5-9, are about the different technologies the team uses, and the subsequent pages refer to the Images, Fig. 10; Publications, Fig. 11; and one of the text pages, Fig. 12. In this lay out it simulates

Conclusion

In conclusion, I have made a report on my project and the methodology and results of said project, constructing a home page. I have enjoyed my stay and am thankful for the opportunity. I have learned much about the opporations at AEDC and the people and equipment involved. I have learned many UNIX commands and much about the Internet. I have also learned HTML and how to construct a home page, and this will be a valuable skill that I may use in the future.

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5. Werbach, Kevin "The Bare Bones Guide to HTML." @ http://werbach.com/barebones/

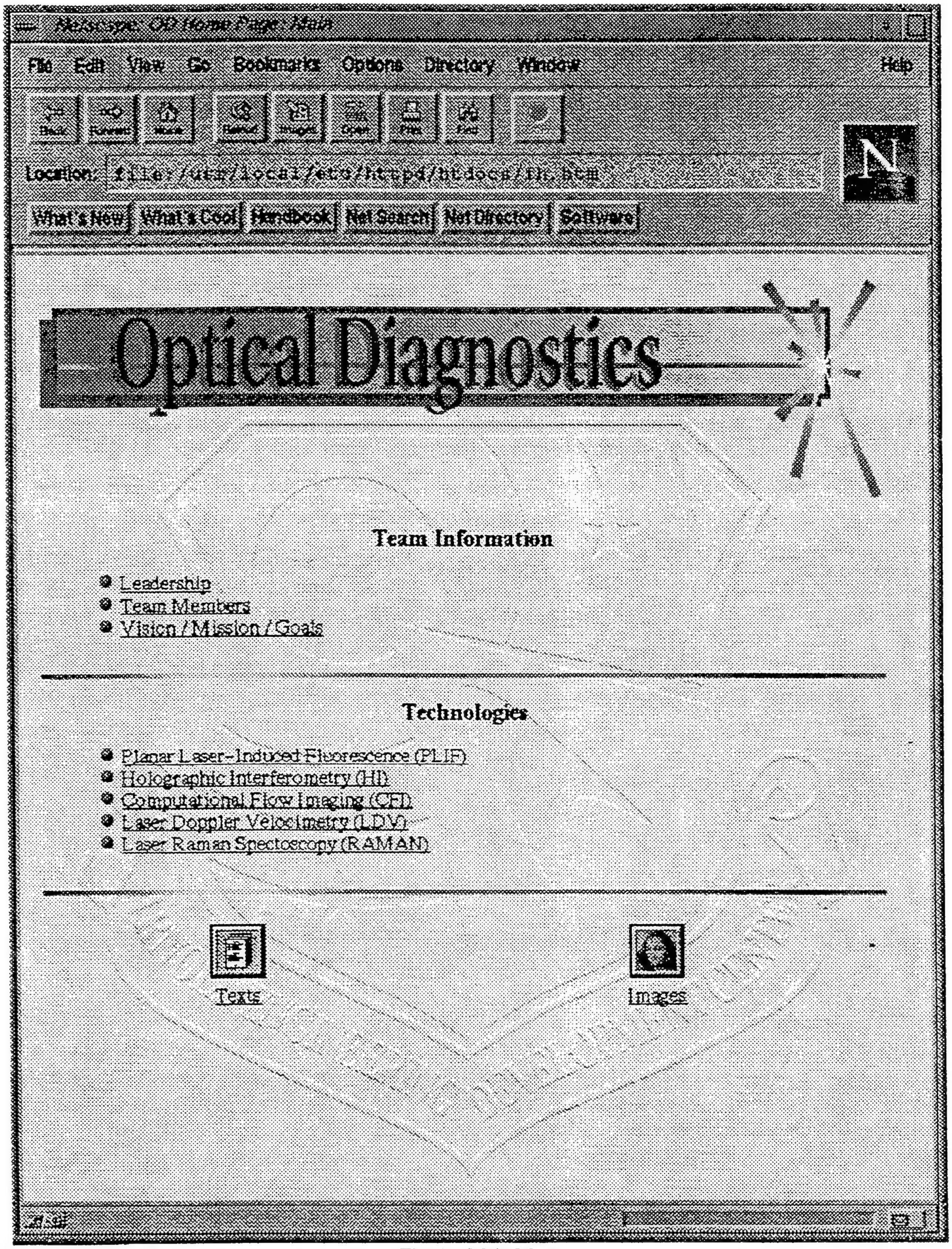


Fig. 1. Main Menu

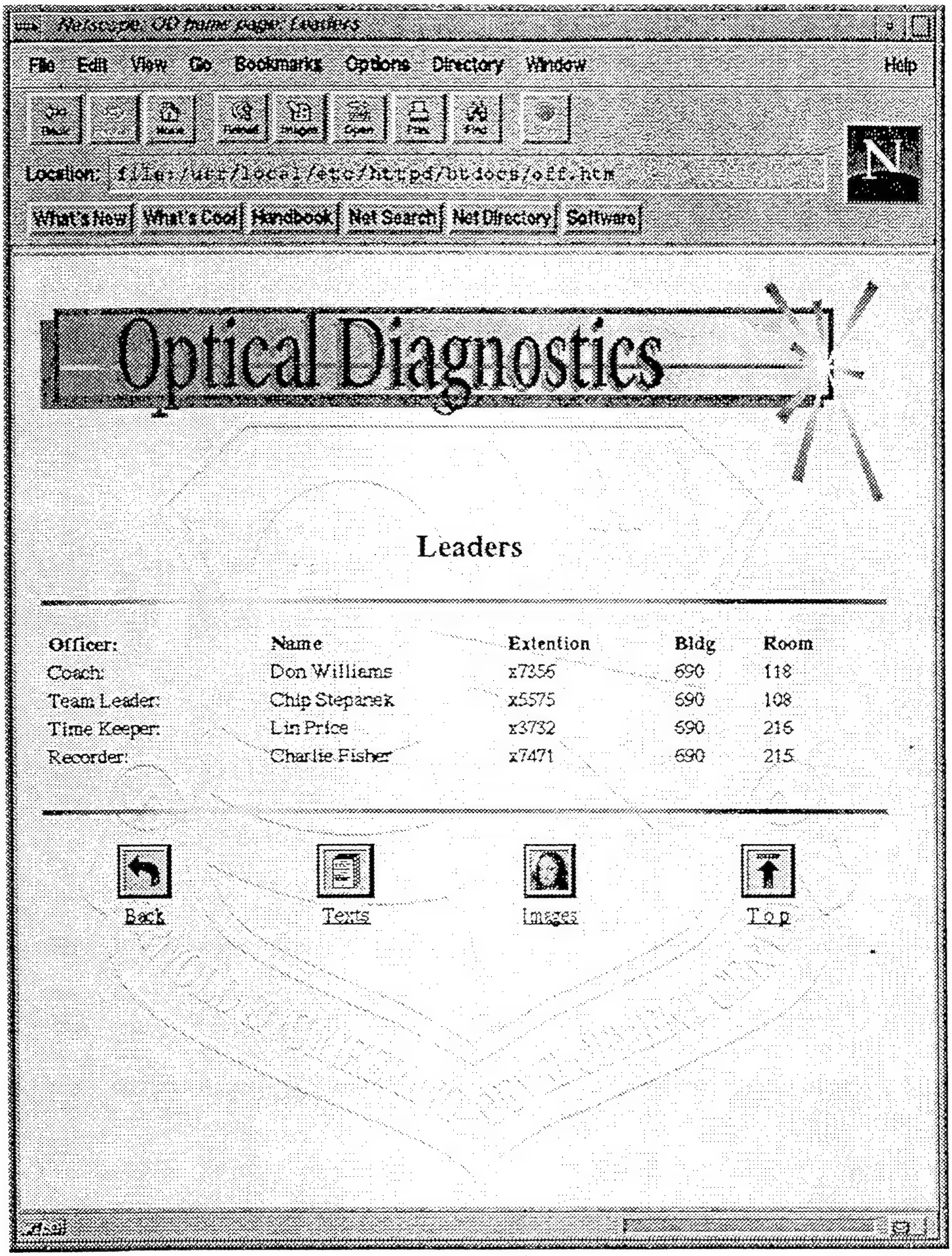
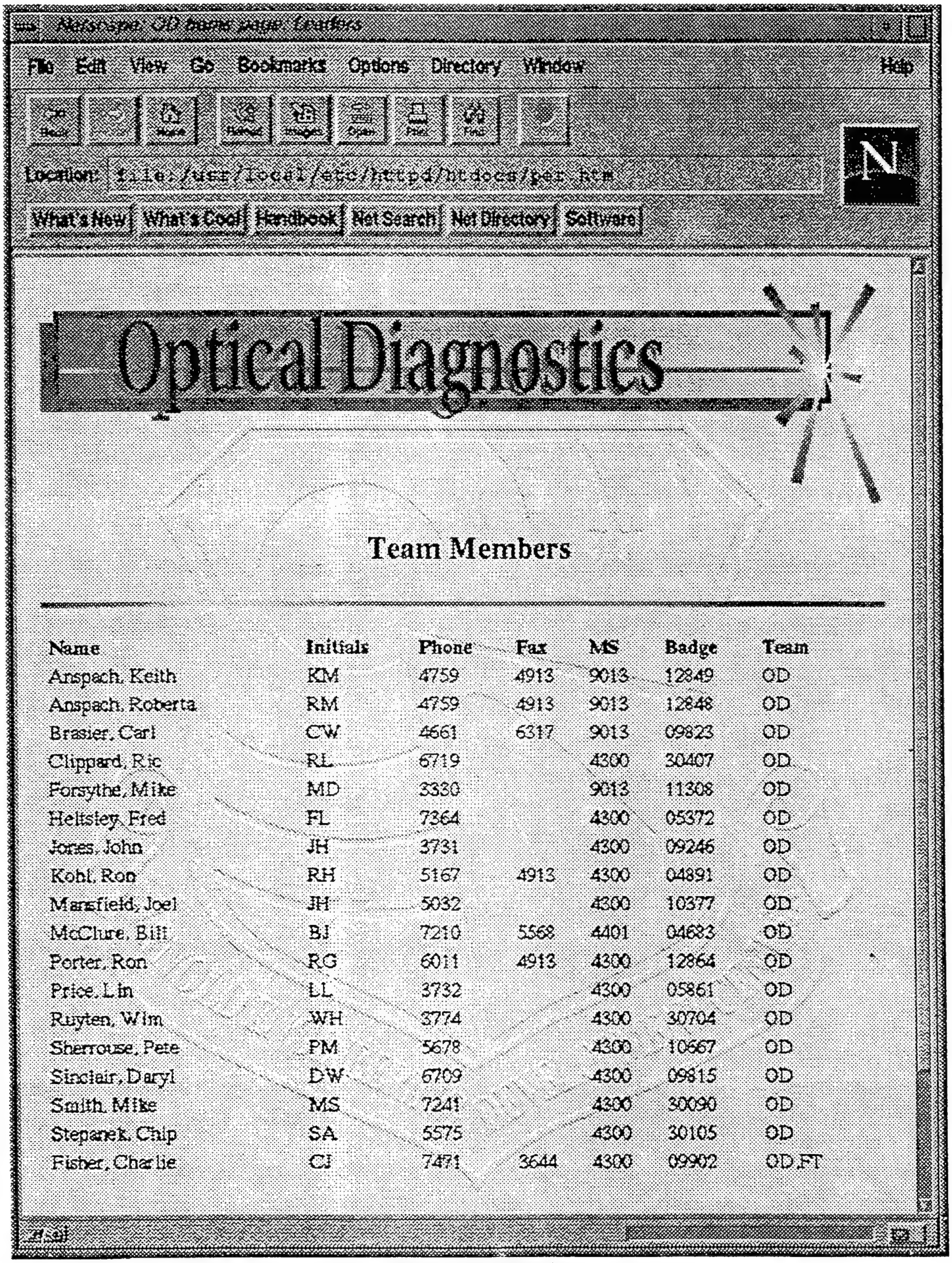


Fig. 2. Leaders



Team Members

Name	Initials	Phone	Fax	MS	Badge	Team
Anspach, Keith	KM	4759	4913	9013	12849	OD
Anspach, Roberta	RM	4759	4913	9013	12848	OD
Brasier, Carl	CW	4661	6317	9013	09823	OD
Clippard, Ric	RL	6719		4300	30407	OD
Forsythe, Mike	MD	3330		9013	11308	OD
Heltsley, Fred	FL	7364		4300	05372	OD
Jones, John	JH	3731		4300	09246	OD
Kohl, Ron	RH	5167	4913	4300	04891	OD
Mansfield, Joel	JH	5032		4300	10377	OD
McClure, Bill	BJ	7210	5568	4401	04683	OD
Porter, Ron	RG	6011	4913	4300	12864	OD
Price, Lin	LL	3732		4300	05861	OD
Ruyten, Wim	WH	3774		4300	30704	OD
Sherrouse, Pete	PM	5678		4300	10667	OD
Sinclair, Daryl	DW	6709		4300	09815	OD
Smith, Mike	MS	7241		4300	30090	OD
Stepanek, Chip	SA	5575		4300	30105	OD
Fisher, Charlie	CJ	7471	3644	4300	09902	OD,FT

Fig. 3. Team Members

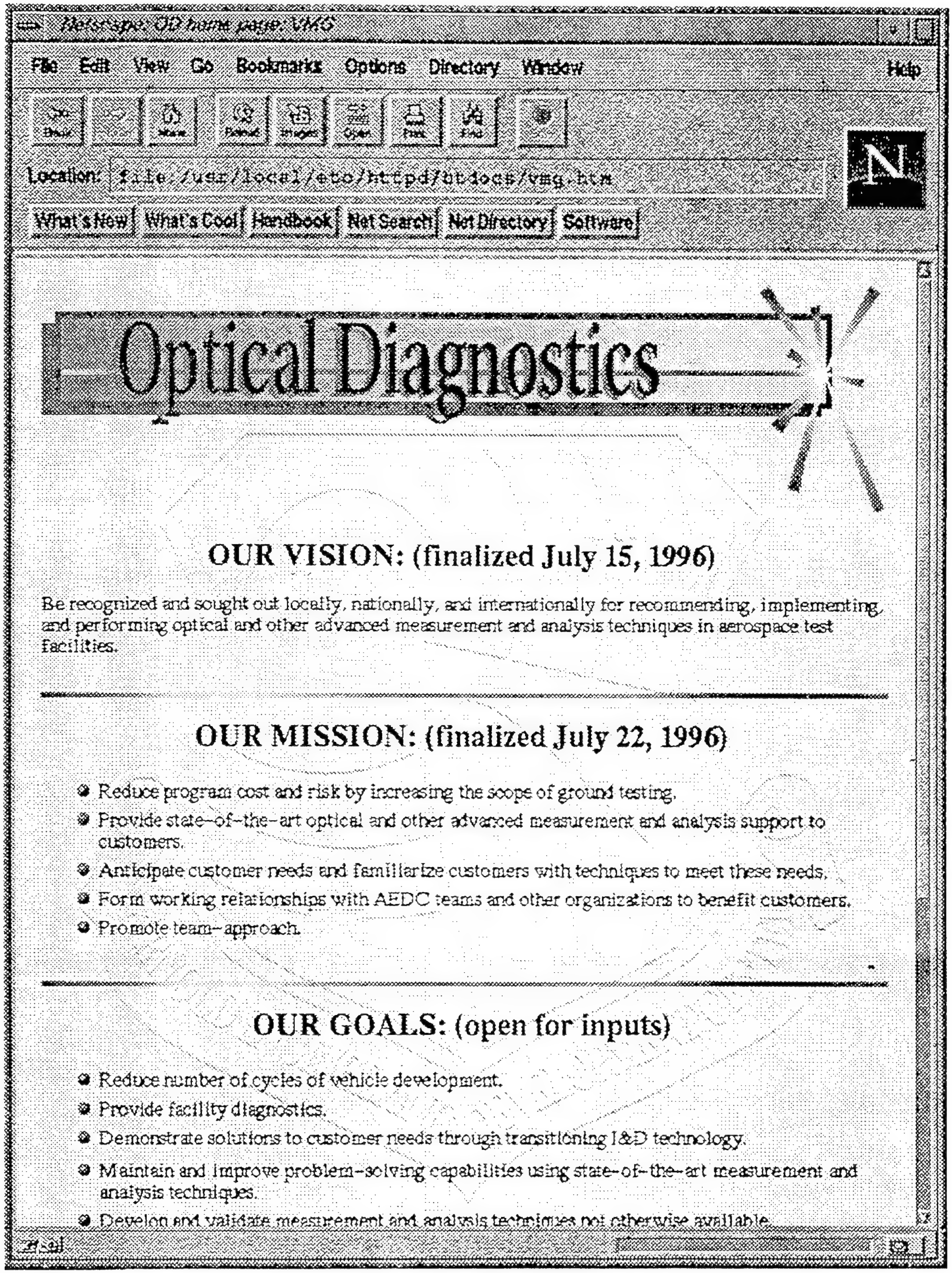


Fig. 4. Vision/Mission/Goals

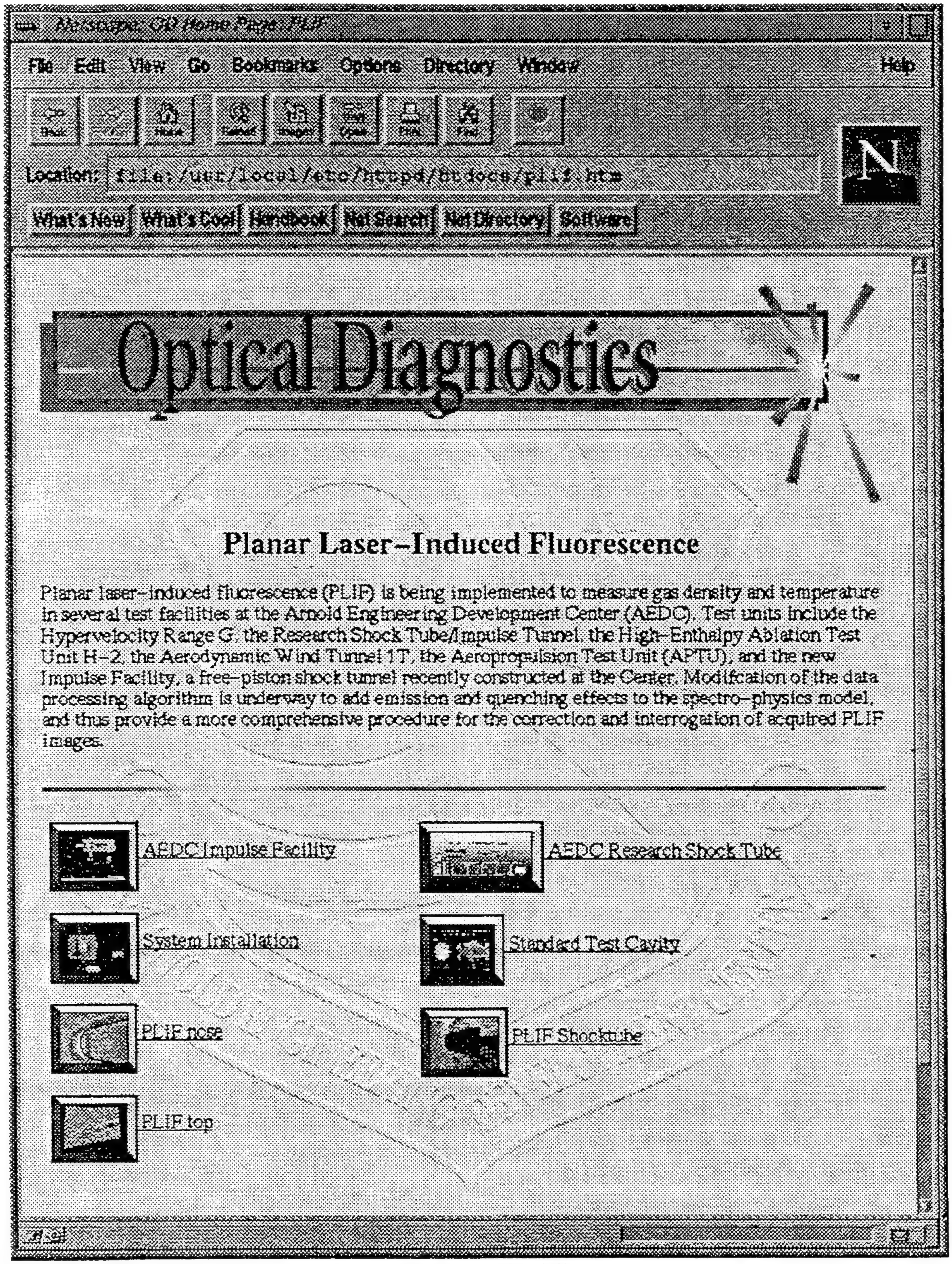


Fig. 5. Planar Laser-Induced Flourescence

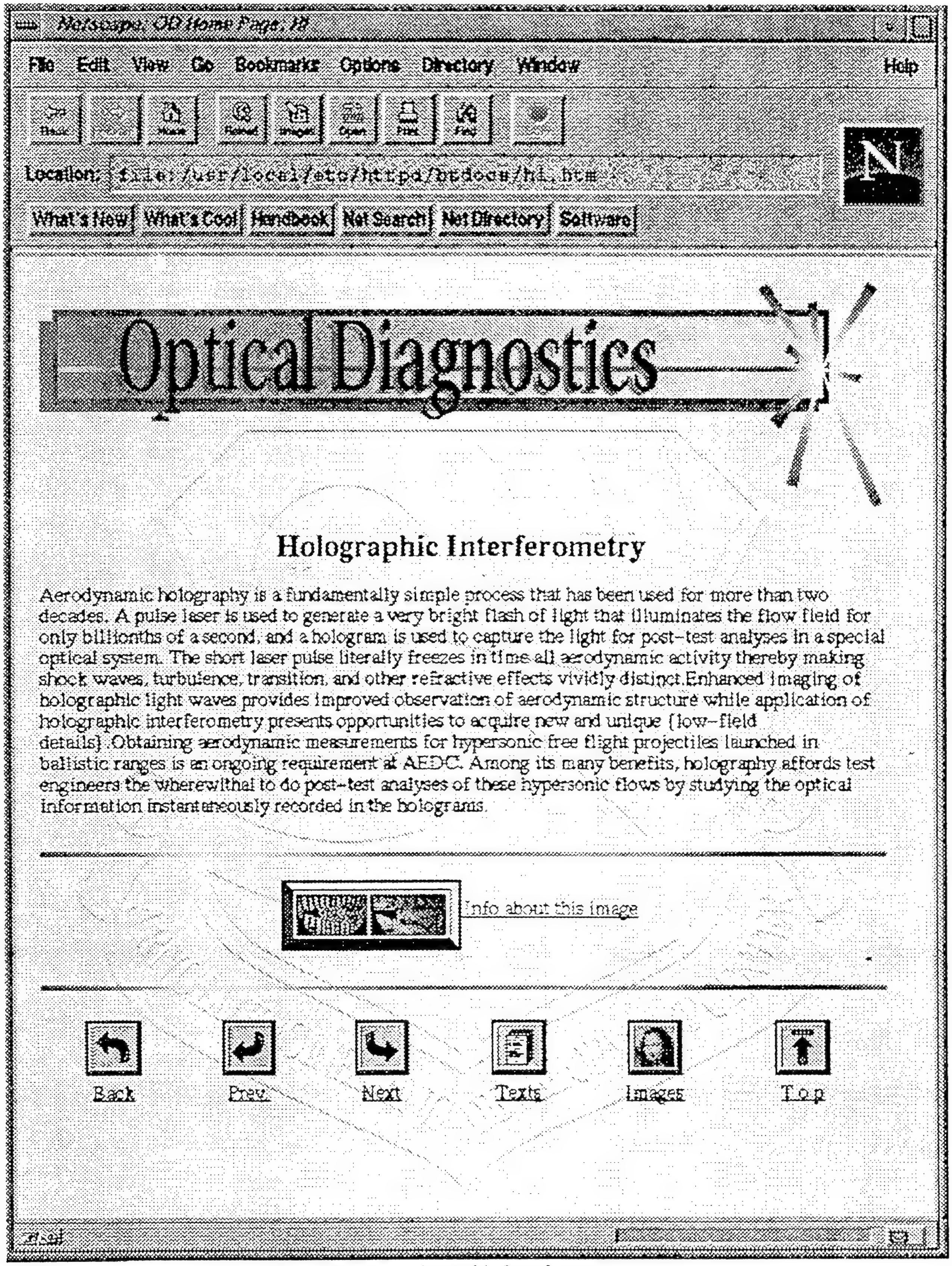


Fig. 6. Holographic Interferometry

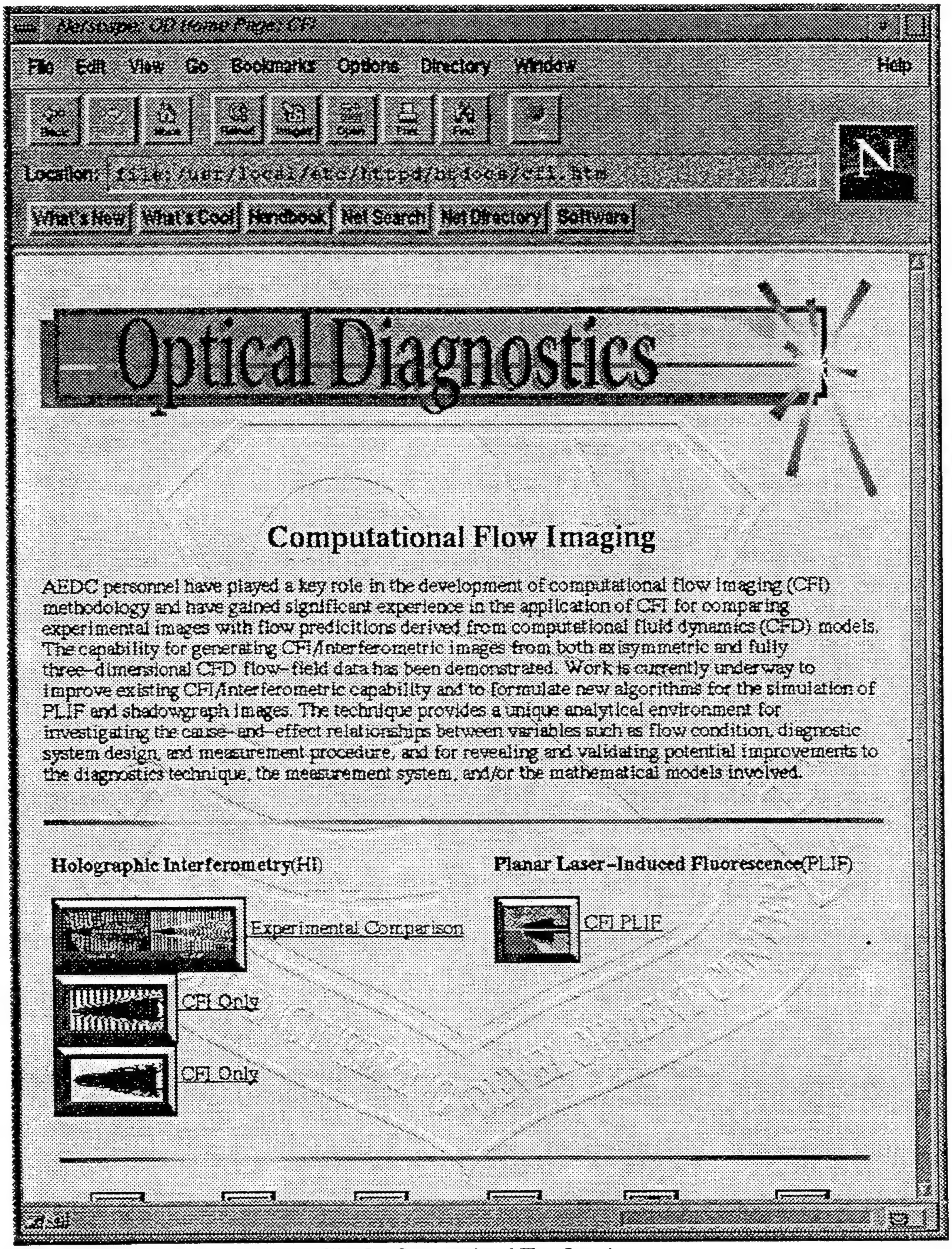


Fig. 7. Computational Flow Imaging

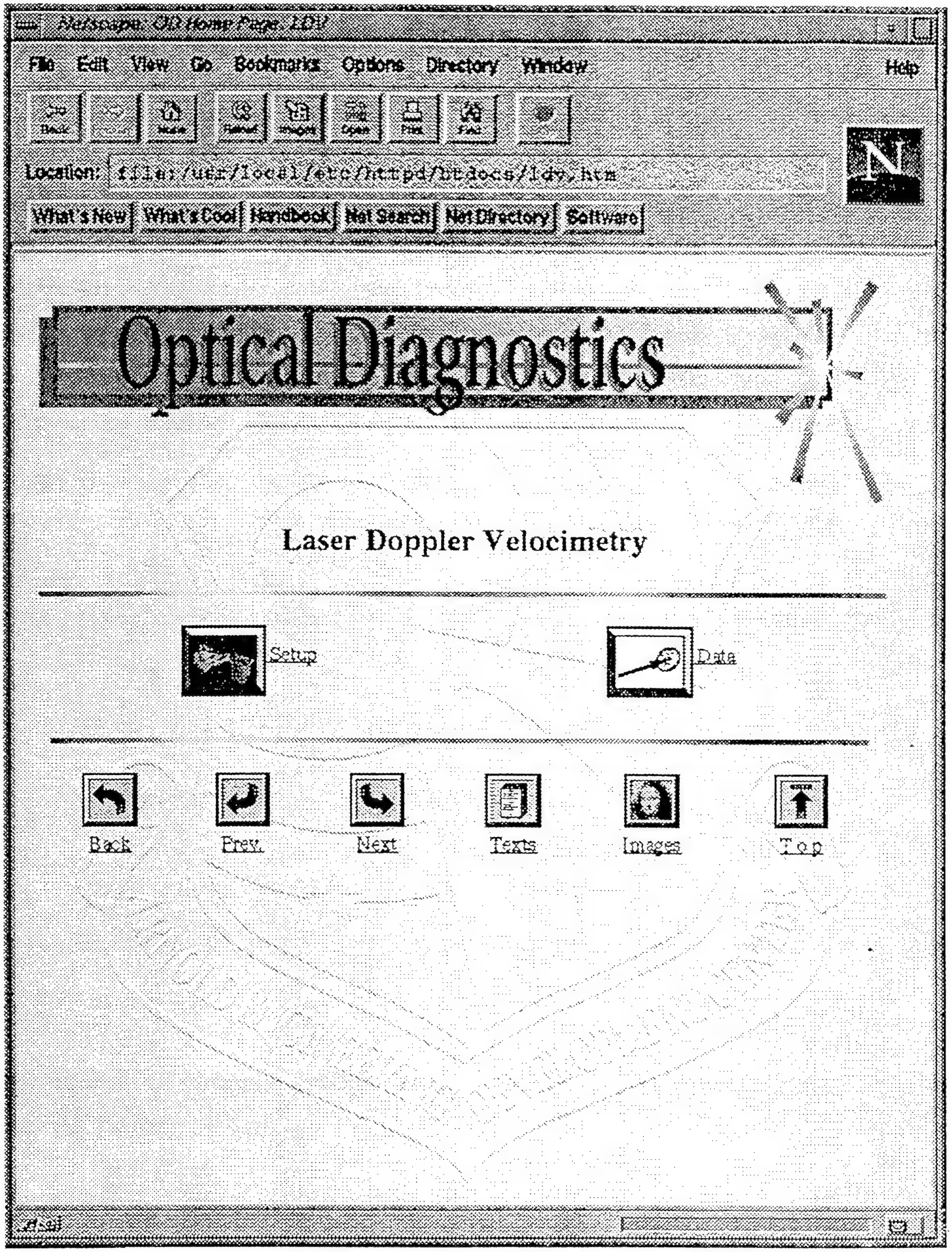


Fig. 8. Laser Doppler Velocimetry

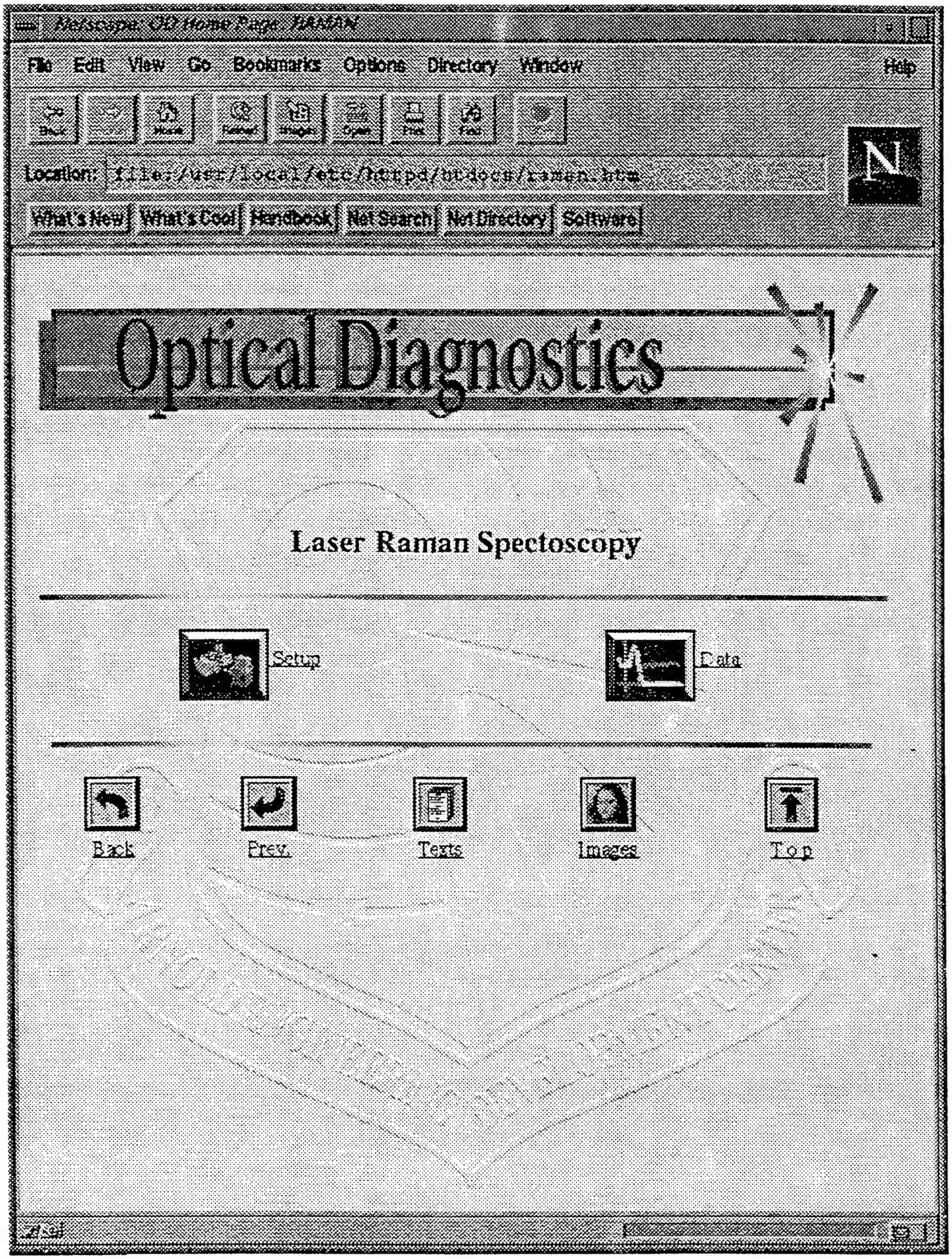


Fig. 9. Laser Raman Spectroscopy

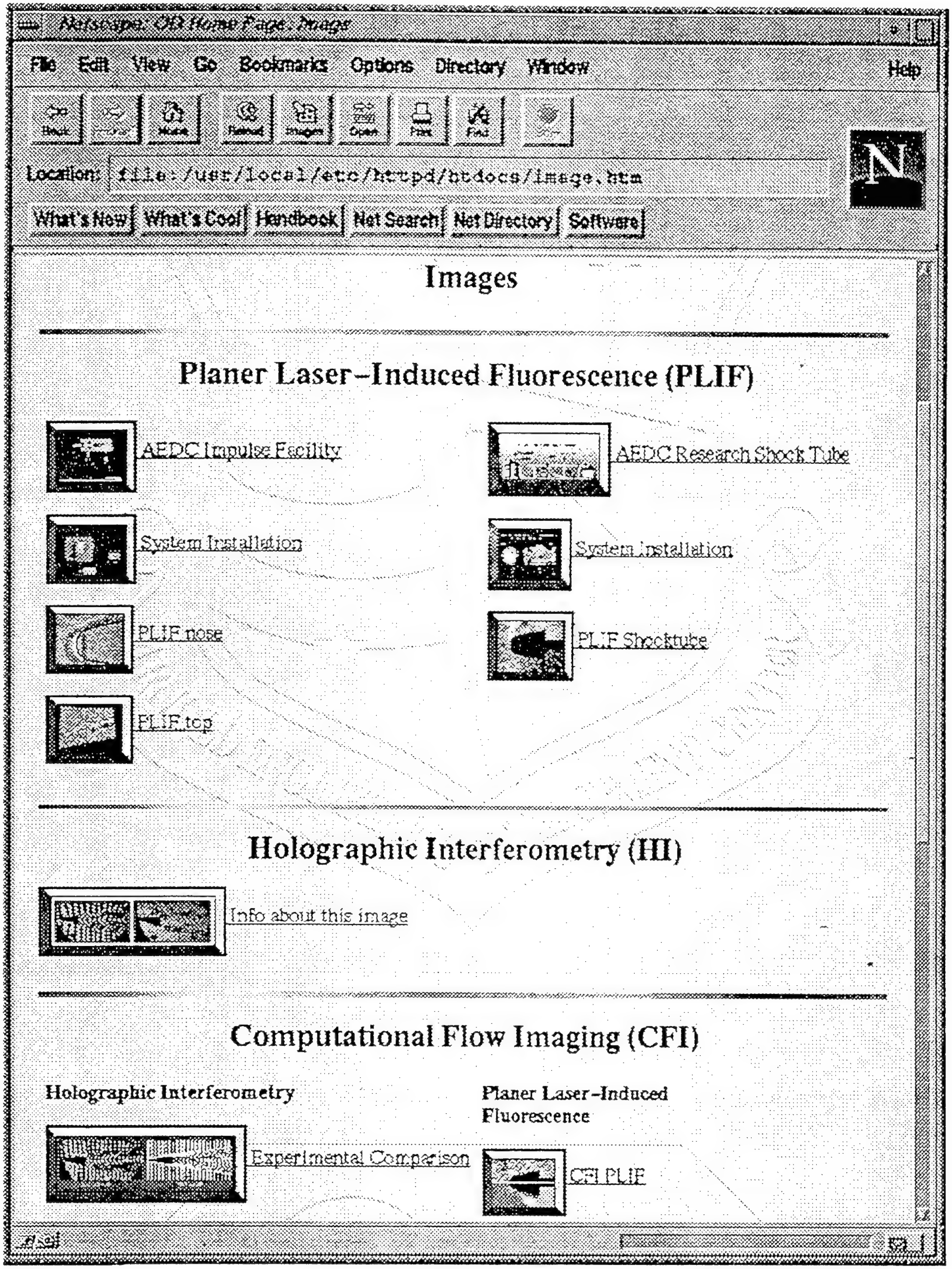


Fig. 10. Images

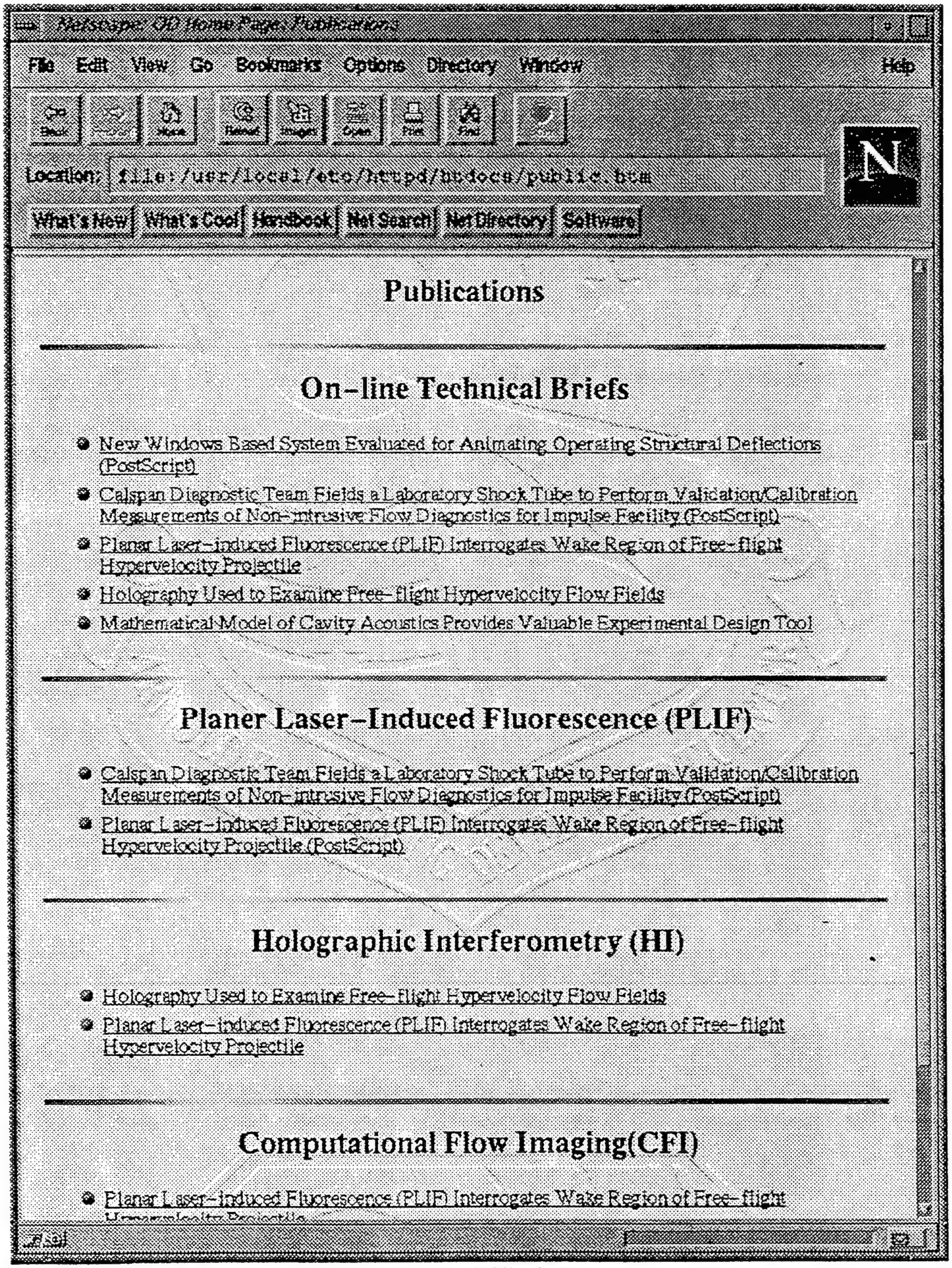


Fig. 11. Publications

Netscape: OD Home Page: Text 2

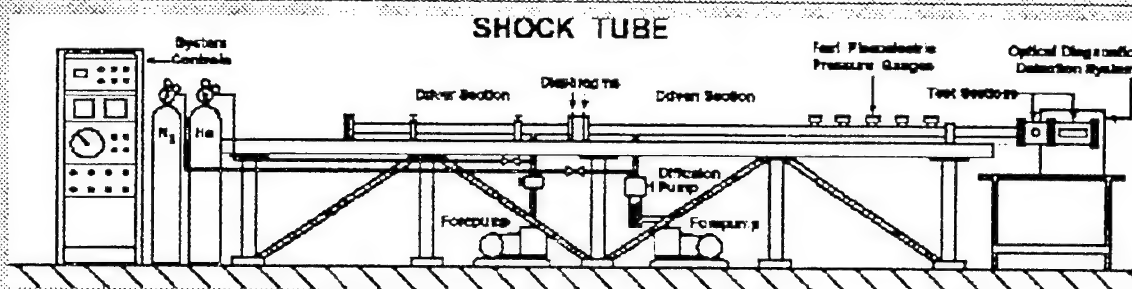
File Edit View Go Bookmarks Options Directory Window Help

Location: file:/usr/local/etc/httpd/htdocs/Text/2/stbrief.html

What's New | What's Cool | Handbook | Net Search | Net Directory | Software

CALSPAN AEDC OPERATIONS TECHNICAL BRIEF

CALSPAN DIAGNOSTIC TEAM FIELDS A LABORATORY SHOCK TUBE TO PERFORM VALIDATION/CALIBRATION MEASUREMENTS OF NON-INTRUSIVE FLOW DIAGNOSTICS FOR IMPULSE FACILITY



Use of a laboratory shock tube to economically provide repeatable, well-characterized flowfields is critical for the demonstration, validation and calibration of diagnostic systems to be used in characterizing the aerodynamic flow in the high-pressure, high-enthalpy Impulse Shock Tunnel Facility at AEDC.

Historically, shock tube facilities have been useful in the study of high-temperature gas dynamic phenomena because they provide a localized region of high-temperature, high-pressure gas of well-known conditions in an accessible, easily operated laboratory device. AEDC's shock tube was constructed in the 1970's and was last used for research in 1985. It was refurbished and returned to operational status in 1993 to support the validation and calibration of aerodynamic flow diagnostics being developed for use in the Impulse Shock Tunnel, under construction at that time. The shock tube, shown below, consists of three chambers separated by aluminum diaphragms: (1) a high pressure driver gas section, (2) a a medium pressure driver gas section, between the two diaphragms, and (3) a low pressure driven (test gas) section.

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ARVIN CALSPAN CORPORATION

The driver sections are filled with helium, and the test gas region is filled with air, N_2, NO, etc., depending on the molecular species of interest. When the firing sequence is initiated, a fast-operating

ok

Fig. 12. Text

MODERNIZATION OF THE AEDC TURBINE ENGINE TEST AND ANALYSIS STANDARD COMPUTER SOFTWARE

Michael R. Munn

Coffee County Central High School

Manchester, TN 37355

Final Report for:
High School Apprenticeship Program

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC
and
AEDC

August 1996

CONVERSION AND TESTING OF THE T.E.T.A.S ROUTINES

Michael R. Munn
Coffee County Central High School

Abstract

The Turbine Engine Test Analysis Standard (TETAS) computer software is a combination of subroutines and functions commonly used when evaluating the data from the turbine engine test cells. These subroutines include functions that find maximum and minimum values, averages, and various other procedures. During the testing the engineer will input data points from the engine. This information will run through the subroutines and the results obtained will give the engineer an idea of the engine's performance. In an attempt to modernize the software, by making the routines more efficient and more transportable from one computer platform to another they are being converted from FORTRAN to C.

Acknowledgments

I would like to take this time to thank the mentors that I worked with this summer and all the people who helped me while I was here. First, I would like to thank Cecil Lewis. Although he wasn't my real mentor, he helped me a great deal. Next, I would like to thank Joe Thompson, my real mentor. Without him I might never had a chance to be a part of the program this summer. Thank you. Finally, I would like to thank all the people around my cubicle and the people I worked with for making me welcome during my time here.

CONVERSION AND TESTING OF THE T.E.T.A.S ROUTINES

Michael R. Munn

INTRODUCTION

The Turbine Engine Test Analysis Standard is a group of routines used to evaluate turbine engine test data. While the engine is running the engineer will input data points from the engine being tested. (See Appendix, Figure 1. This diagram shows the point of installation of the engine in the test cell and some points important for the testing.) The test data points will be run through the TETAS routines to give the engineer an idea of the engine's performance.

Approximately 20 years ago, this standardized turbine engine performance analysis program was established for use in the Engine Test Facility (ETF). Since then the turbine engine configurations have changed, and computers and operating systems have advanced. The objective of this effort was to modernize the TETAS software for use in the turbine engine test units at AEDC. This improved software would then be available to all ETF test groups and customers. The overall modernization process consisted of many changes that needed to take place. This included the removal of common and goto statements, basic clean-up (indention, comments, etc.) and many other coding modifications. To help with the modernization, I translated a portion of the programs from FORTRAN to C. (Turrentine 5,7) Remove

METHODOLOGY

Before the programmer is able to convert these routines he or she must first have a clear understanding of the syntax and construction of both FORTRAN and C.

In order to implement the conversions, I had many lessons in both. By reading various programs and watching experienced programmers at work, I was able to understand the science behind computer programming. I also learned valuable information of both FORTRAN and C.

FORTRAN (FORmula TRANslation) is considered a mathematical computer language. It has been around for quite some time. In the beginning it was FORTRAN 2, then progressed into FORTRAN 4, 77, and eventually FORTRAN 90. This summer I mainly worked with FORTRAN 77.

This computer language is very useful but it requires a structured format when typing the code. For example, the commands of the program must be placed in column seven when typing for the program to compile properly. Also, only one command is acceptable per line. Little rules like these cause FORTRAN programs to be large and harder to type (McCracken 1,5).

C on the other hand is a much smaller, more basic language. There are fewer keywords in C than almost any other language. Right now C is the most used language around. In fact, almost 95% of the programs written today are in C. This is because of a few unique features of this extremely powerful language (Kelley, Pohl 1,3).

C is compact. As I stated before , C is one of the smallest languages. The programmer can decide how large or how small to make the program. For example, I wrote a program in FORTRAN with 15 lines of carefully typed out code. The same program was rewritten in C in just three lines!!

C is fast. Because of its smaller size, C is able to run a program much faster

than FORTRAN. Remember the identical programs? The 15 lines of FORTRAN and the three lines of C? Obviously the C program will run much faster than the FORTRAN not only because of the size but also because it is so close to the hardware and the commands are so powerful. These characteristics of C make it perfect for the TETAS routines.

C is versatile. C works very close to the hardware of the computer. This allows the programmer to know exactly what will happen in the program. It also allows the C program to work on a variety of different machines. Not so with FORTRAN. FORTRAN is a higher level language, like PASCAL or BASIC. This means that it doesn't work so close to the computer. This makes the range of machines the FORTRAN program will work on more limited.

Once the programmer can read, write and, most importantly, understand FORTRAN and C, he or she can begin the conversion process. After the subroutine is converted into C, it is tested by itself within a single program. To do this the programmer must write a main program that will call the subroutine being tested. This process is called the subroutine testing.

If the program can pass this test free of errors then it proceeds to the integration testing. This is when the subroutine is called from the main integration test program. To do this a main program must be written that passes the correct number of arguments to each subroutine. This is how the subroutines will be used during testing so it is most important to be sure there are no errors in this stage. This main program will call every one of the TETAS routines to check them all at once. After this is accomplished without any problems the subroutines can be integrated into the system.

There were 96 different TETAS subroutines in all. During the summer I worked with about 8 of them. See Appendix, Figure 2. This table lists the subroutines that I worked with and their uses in the system.

RESULTS

After the subroutines are put into the system they are ready for use. During the loading of the main performance program, many of these subroutines are taken from the library and used for calculations. The performance program will take information from the engine being tested and, using TETAS routines and other calculations, send back engineering data to the engineer for evaluation. This data is compared to the data received from years of testing the customer's engines. This is how the testing takes place an how the routines will be used. Now that the routines are written in C rather than FORTRAN, they will run much faster, take up less space, and be more efficient and transportable for integration into the newer computer systems. See Appendix, Figures 3 and 4. These two graphs compare two important characteristics of FORTRAN and C. The first compares the code size with some of the programs that I worked with over the summer. The second compares the running time of the different types of code.

SUMMARY

This summer has been extremely beneficial to me. When I first started I had no previous experience in computer programming. But now I understand FORTRAN and C well enough to translate one to the other. I have also been exposed to the most advanced equipment available. I worked with the PC, receiving courses in Windows

'95, Excel, Access, and File Management for Windows '95. I also had the opportunity to work with the Silicon Graphics Incorporated Machine (SGI). This is an extremely powerful machine on which I did most of my work with the TETAS software. By working with these machines I was able to understand how the networking systems worked and how they were operated and maintained. I also learned some UNIX commands that will be helpful in the future. By working with the TETAS routines I became more familiar with the processes of turbine engine testing and felt as if I had accomplished something of worth when I was finished. This program has been a very valuable experience for me.

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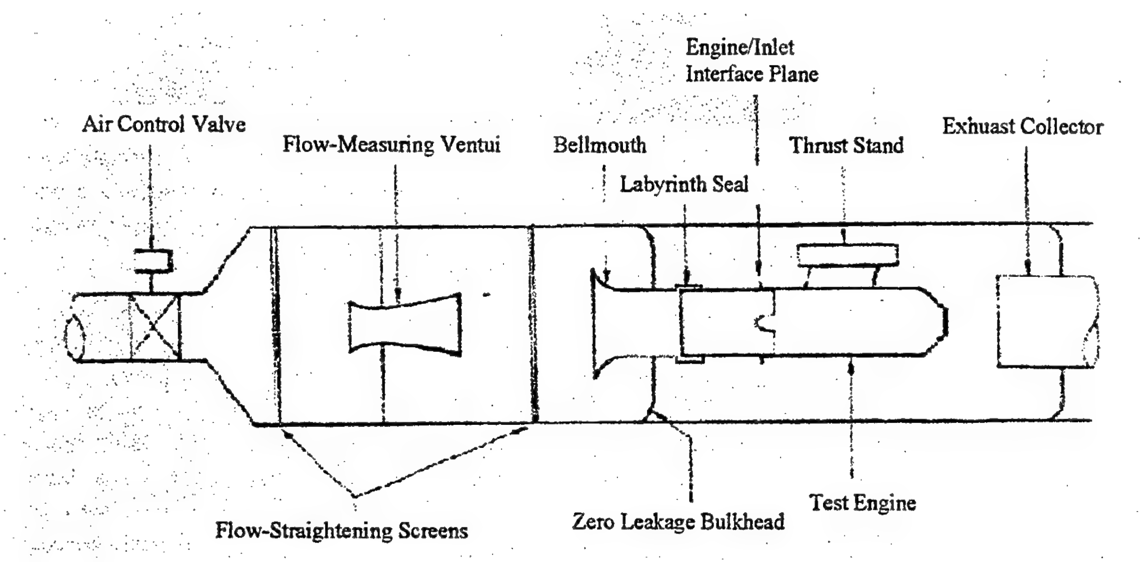
Dist B Remove

AEDC-TR-78-31. Turrentine, W. A., H. S. Hinds, and J. W. Davenport. Turbine Engine Test Analysis Standard Program Description. ARO, Inc., 1978.

APPENDIX

Figure 1

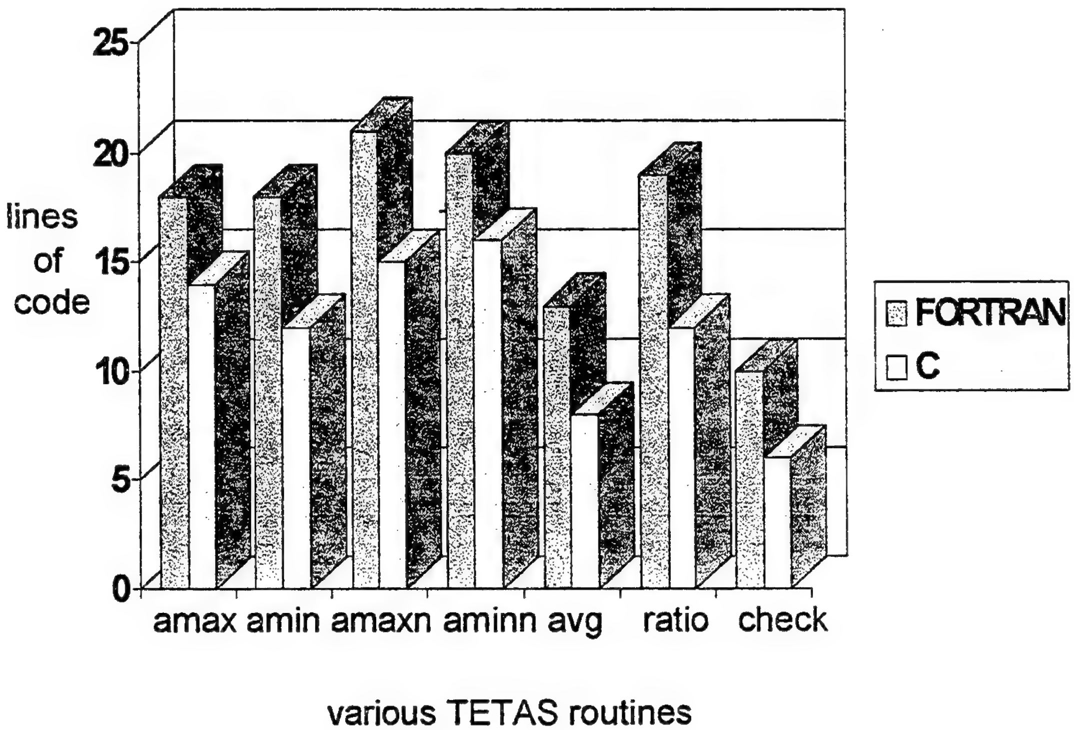


This diagram show the point of installation of the Test Engine and various points used during the testing. The TETAS computer software will be used during testing in cells such as this one.

Figure 2

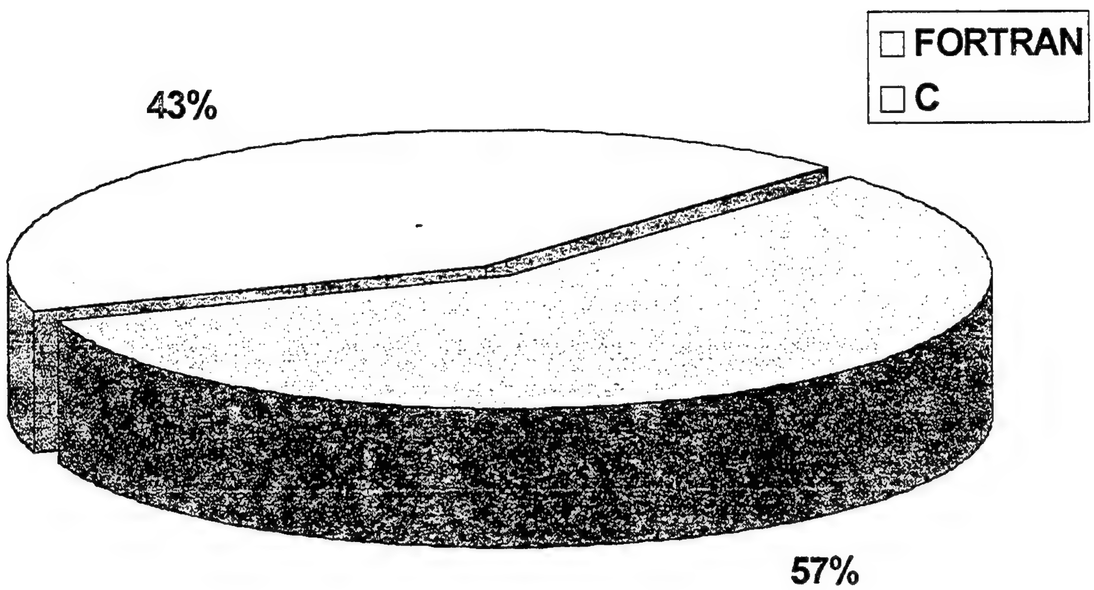
amax.f	returns the maximum value of an array of values
amin.f	returns the minimum value of an array of values
amaxn.f	returns the maximum value disregarding pre-determined intervals
aminn.f	returns the minimum value disregarding pre-determined intervals
avg.f	calculates the average
ratio.f	calculates the ratio of a set of values to the average of the values
check.f	deviation and tolerance check

Figure 3



This graph compares the code size between FORTRAN and C with a sample of the TETAS routines. The FORTRAN is the darker gray area and the C is the lighter gray area. As you can see, in each case the code size is greatly decreased after the conversion.

Figure 4



This graph compares the running time of FORTRAN and C. The FORTRAN code is represented by the darker gray area and the C code is represented by the lighter gray area. The running time was decreased through the tran slation to C.

TURBINE ENGINE MODEL LIBRARY

Daniel B. Sipe

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Manchester, TN 37355

Final Report for:
High School Apprentice Program
Arnold Engineering Development Center

Sponsored by:
Air Force Office of Scientific Research
Bolling Air Force Base, DC

and

Arnold Engineering Development Center

August 1996

TURBINE ENGINE MODEL LIBRARY

Daniel Sipe
Coffee Co. Central High School

Abstract

A turbine engine model library was created for easy access to turbine engine computer models. A DOS directory structure was used to organize the models which permits several levels of categorization and enables expansion to accommodate additional models. Hypertext Markup Language was used to design a user interface for accessing the contents of the Library. Twenty-three engine models were retrieved from various computers and are included in the turbine engine model library. The result is an Internet type page which provides access to the library via the internal web at Arnold Engineering Development Center.

TURBINE ENGINE MODEL LIBRARY

Daniel Sipe

INTRODUCTION

Turbine engine models are abundant at Arnold Engineering Development Center(AEDC) and a centralized, organized approach was needed for easy access to any particular turbine engine model. Therefore, a turbine engine model library was created in order to provide simple access to detailed listings of these engine models.

DISCUSSION OF PROBLEM

The turbine engine models at AEDC were in poor organization. The engine models could be found in a variety of places on the base including two mainframes, several personal computers(PC), and digital tape. One or more copies of a particular engine model could be located at any of these locations. The problem was locating one of each engine model, retrieving the engine model, identifying it, and finally categorizing it. Additionally, an organizational framework and interface was required so that the engine models could be accessed by a wide variety of engineers and programmers.

METHODOLOGY

There were two main tasks in building the turbine engine model library. The first step was to organize the engine models. The organization required locating, retrieving, identifying, and categorizing the engine models. This process helped design the framework for the library. The second step was to design a user interface which was needed for easy access to and viewing of the library.

The first task in designing the library was to organize the engine models. In order to organize the engine model it was necessary to design a framework to categorize them. After locating an engine model, it was retrieved and identified which involved searching the files for keywords. The backbone of the framework consists of a list of the manufacturers of the engine models. The engine manufacturer's name (e.g. General Electric or Pratt Whitney) was the most common characteristic found in all the models and therefore, was used as the primary keyword in the search. Once found, other characteristics such as, engine series, and

model identification, typically were found in the neighborhood of the manufacturer's name. The engine series(e.g. F100, F117, J57) was the next level in the framework and consists of a list of the engine models from a specific manufacturer. The engine version (e.g. PW-100 or PW-220) follows by giving a list of versions of a particular engine which specifies the engine's features. Lastly the model identifier (e.g. CCD01194) provides a listing of the files an engine model has which are: fortran source, sample input, sample output, and user manual.

The second step in building the library was to design and build a user interface to provide easy access to the engine models. A web-type interface was chosen because of it's universal familiarity and wide availability at AEDC. Hypertext Markup Language (HTML) was used to provide easy navigation within the diverse library. The interface was designed to function with typical web-type browsers.

RESULTS

The turbine engine model library is accessed by using an Internet type page. The front page contains a list of manufacturers (Figure 1) and an index of all the engine models. The manufacturers are underlined on the page indicating a link to the next page which is the engine series page. The engine series page leads to the engine version page (e.g. Figure 2) and ultimately to the model identifier page. The model identifier page provides a list of files (e.g. Figure 3) which can be assessed for obtaining information as required by the user. The FORTRAN source is the file that contains the computer program listing. The sample input is another file which contains input data for FORTRAN source which is the executable file. The sample output file is data that has been generated through the execution of the FORTRAN source. The last file is the user manual which contains information pertaining to operation of the model. In all, 23 engine models exist in the library and each contains at least a FORTRAN source file.

CONCLUSION

A centralized, organized approach was needed for easy access to detailed listings of turbine engine models. A turbine engine model library was created for simple access to these engine models. The models were found on mainframe, individual personal computers, and digital tape. A framework and interface were

designed and built for easy access to and editing purposes. A "web page" interface was used because of its universal familiarity. The turbine engine model library which was built to house the abundant supply of turbine engines will be made available on the internal web at AEDC.

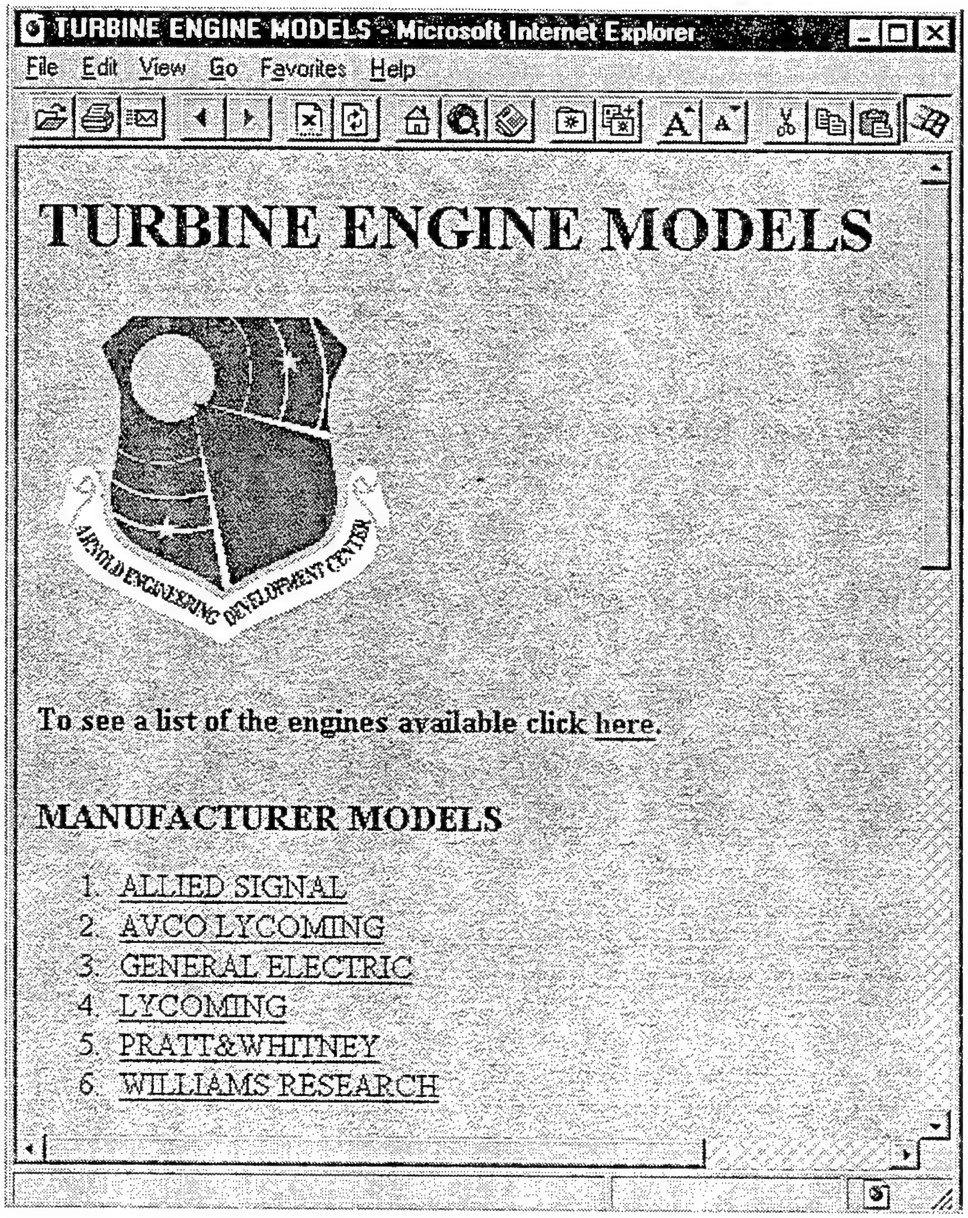

Figure 1. Engine Model Library -Main Index

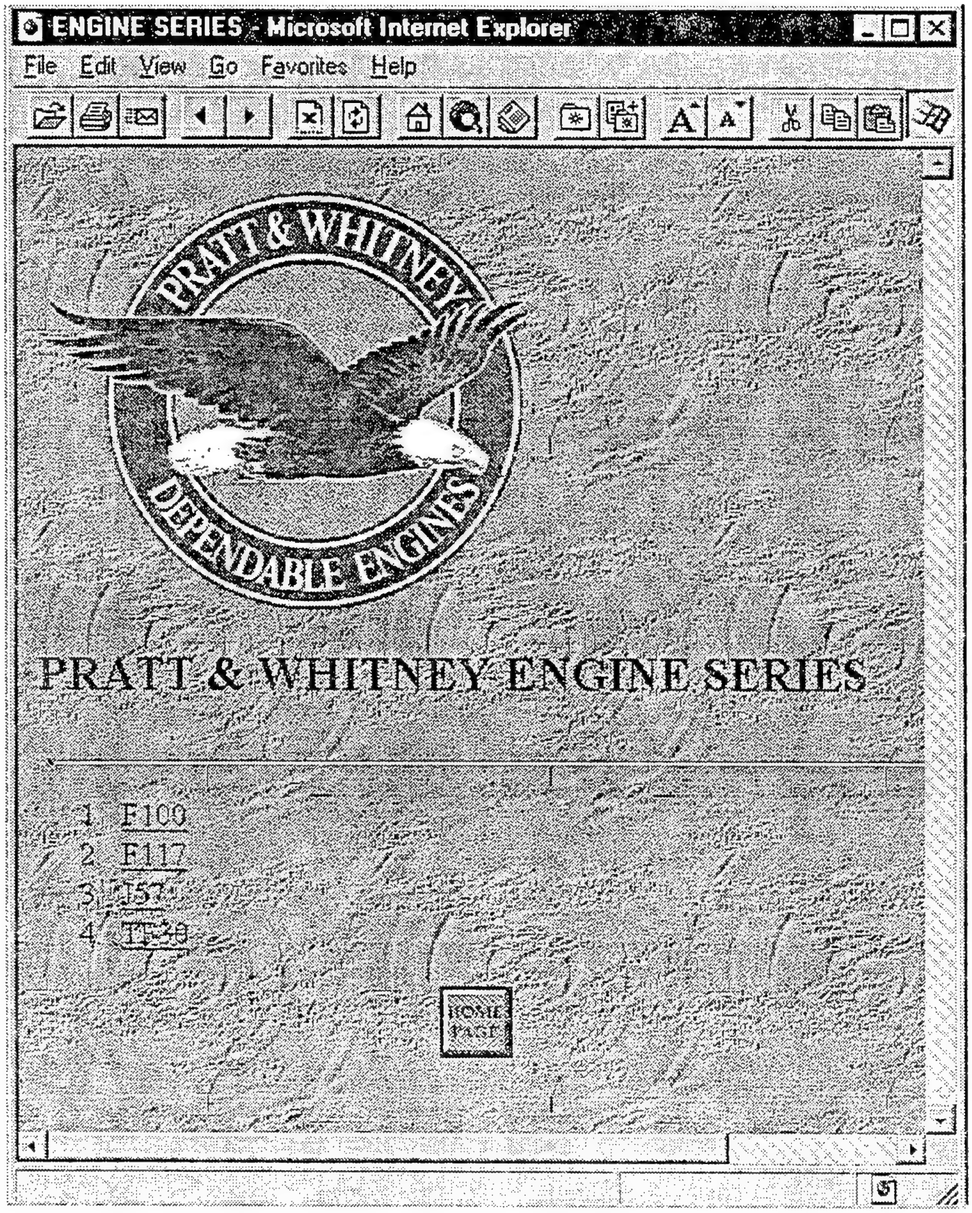

Figure 2. Engine Model Library- Available Engine Models

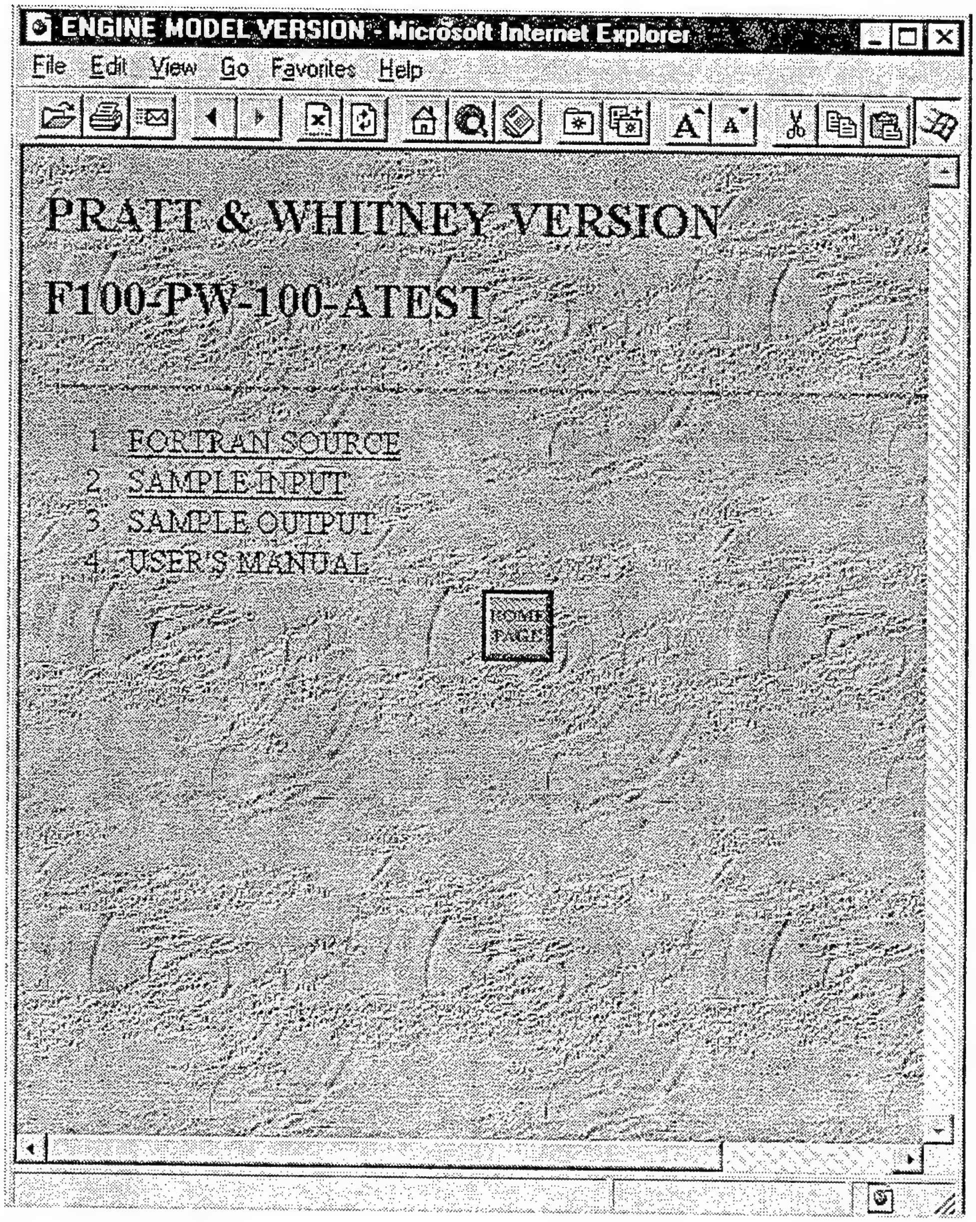

Figure 3. Engine Model Library- Engine Model Files

A METHODOLOGY
FOR ASSESSING
THE PERFORMANCE
OF THE J-4 ROCKET
TEST FACILITY

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Final Report for:
High School Apprentice Program
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A METHODOLOGY
FOR ASSESSING
THE PERFORMANCE
OF THE J-4 ROCKET
TEST FACILITY

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Introduction

The J-4 test complex is one of seven engine test facilities located in Arnold Engineering and Development Center near Tullahoma, Tennessee. The facility was designed to test liquid propellant rocket engines at a simulated altitude of 100,000 feet. Three pump systems, the engine, a steam ejector, and an exhaust plant, create a vacuum by extracting air in the test region to achieve the desired altitude. Prior to ignition, the steam ejector propels steam downward at a high velocity and entrains air in the test region, thus reducing cell pressure. During firing, the rocket exhaust provides the necessary altitude pump, further reducing cell pressure. The steam ejector may be shut down to decrease steam usage but operates again before shutdown. (Fig.1)

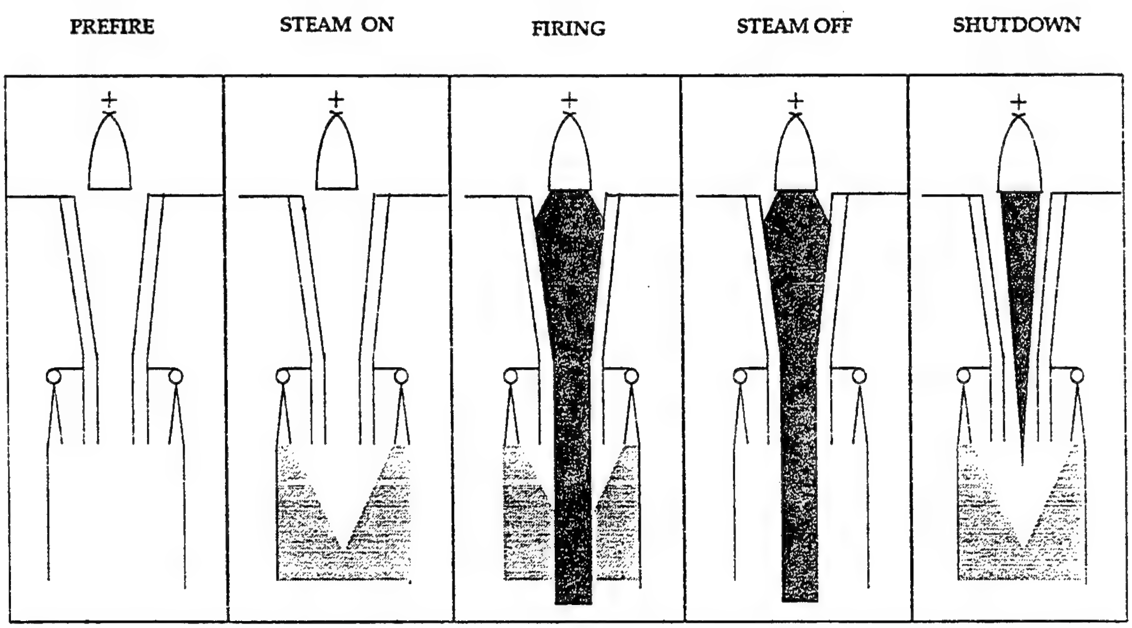

Figure 1. Steam Ejector and Rocket Diffuser Operation

A rocket engine test requires three consumables in sufficient amounts: propellant for fuel, steam for the altitude simulation, and water to cool the exhaust flow. Without one of the basic conditions the test article cannot adequately simulate the desired conditions. There are two types of liquid propellant supply systems available at the J-4 facility : Aerozine-50 & Nitrogen tetroxide and Liquid Oxygen & Liquid Hydrogen. The Aerozine propellant is storable at ambient temperatures and does not require as much special treatment as the liquid Oxygen, which has to be maintained at cryogenic temperatures (166 R).

To provide a general perspective of the consumable limits, a plot displaying the limits was needed. An older chart (Fig. 3 Ref. 1) existed, but the information it contained was outdated and no longer applicable. Using the new chart, a customer can determine J-4 test capabilities for various engine sizes.

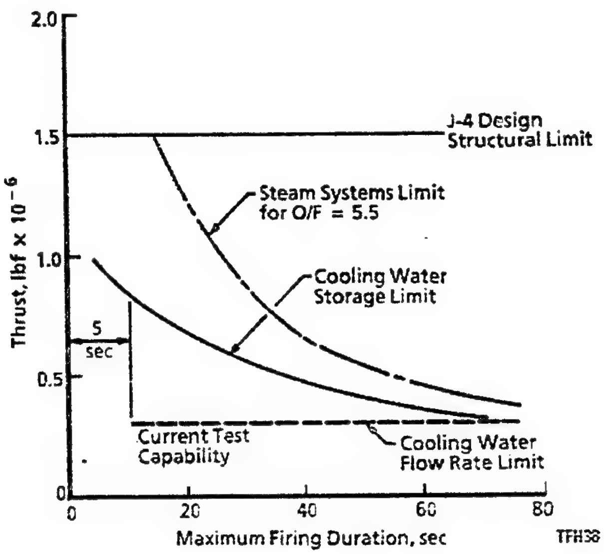

Figure 3. Outdated Test Capabilities Chart

Methodology

To define the parameters of J-4, several basic conservation laws were used (Ref.2). The equation to define the cooling water limit combines the laws of conservation of mass and energy.

$$M_{win} = M_{wout} \times (W_{sc} + M_{rg}) - (W_{sc} \times H_{sc}) - (M_{rg} \times H_{rg}) \times 7.193269230769 \div (H_{win} - H_{wout})$$

where : M = mass flow rate (lbm/sec)
H = enthalpy (Btu/lbm)
W= mass flow rate of steam (lbm/sec)

A list of the assumptions and their values is summarized in Figure 4. Steam profiles were assumed for the AZ50/N_2O_4 (Fig.5) and LOX/LH_2 (Fig. 6) systems. Generally, steam profiles are dependent on the engine size and the test objectives. Run-time durations are to be calculated for each customer as needed. Due to the high flow rates of steam through the J-4 ejector system, a small change in the steam profile will greatly affect facility performance.

	AZ50	LOX
O:F	1.8	6
C*	5700	7600
Cf	1.8	2
Tsc	85	85
Steam Profile	Fig. 5	Fig. 6

Figure 4. Assumptions

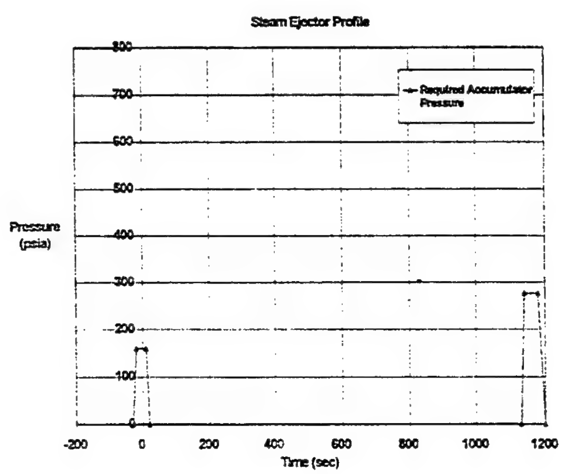

Figure 5. Steam Profile - AZ50

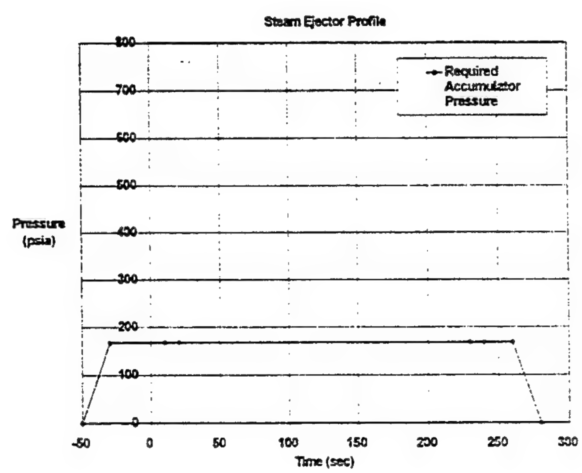

Figure 6. Steam Profile - LOX

Using this information, two charts were made for each propellant displaying the associated performance boundaries of the J-4 test facility. (Fig.11-12)

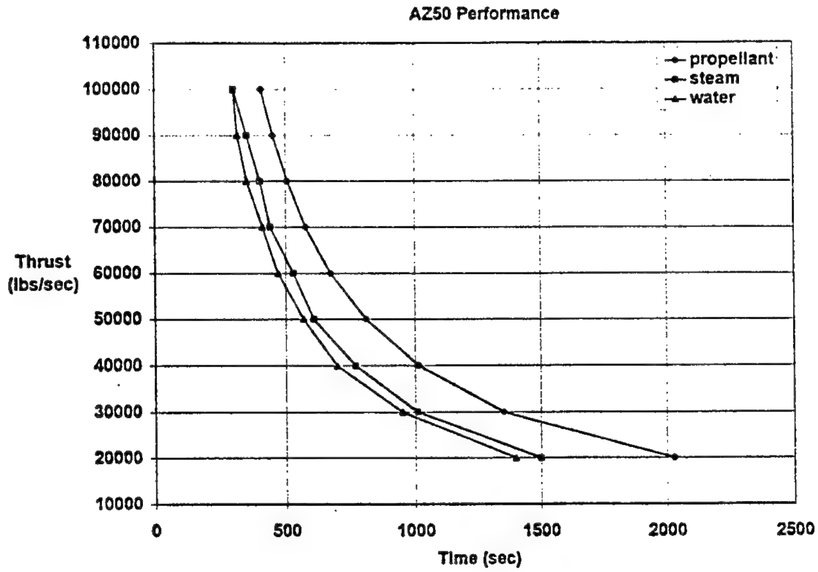

Figure 10. J-4 Test Facility Boundaries for AZ50

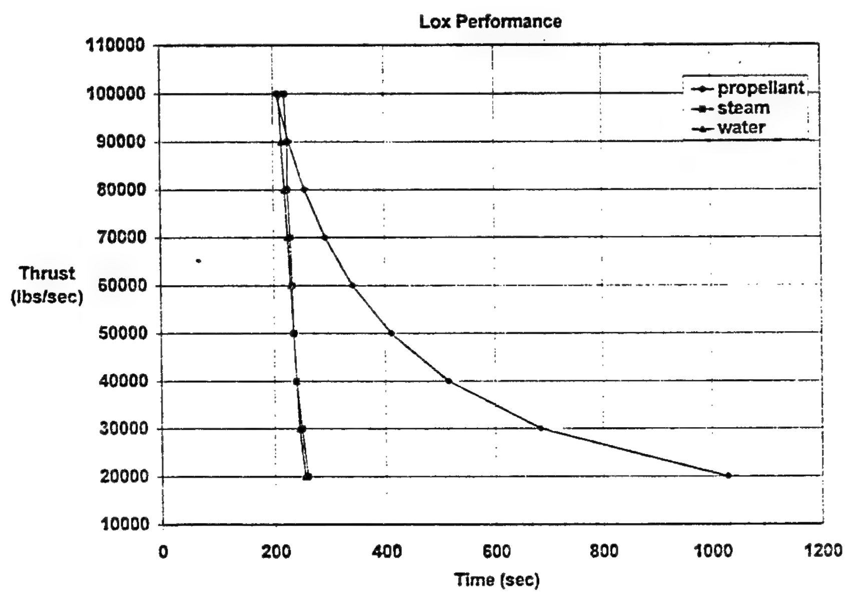

Figure 11. J-4 Test Facility Boundaries for LOX

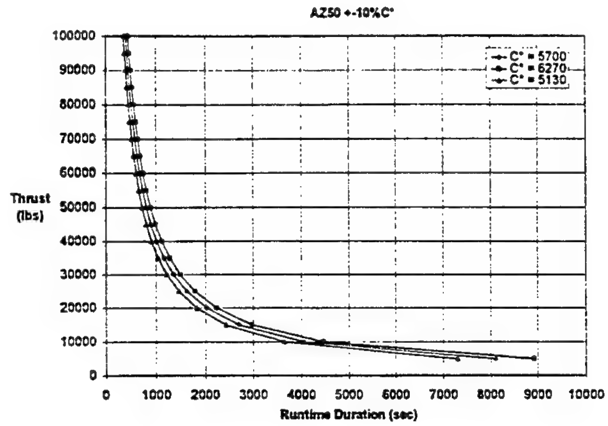

Figure 15. Variation in C* - AZ50

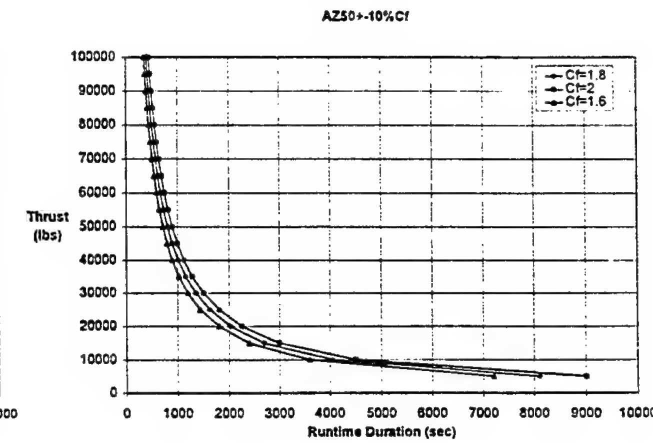

Figure 16. Variation in Cf - AZ50

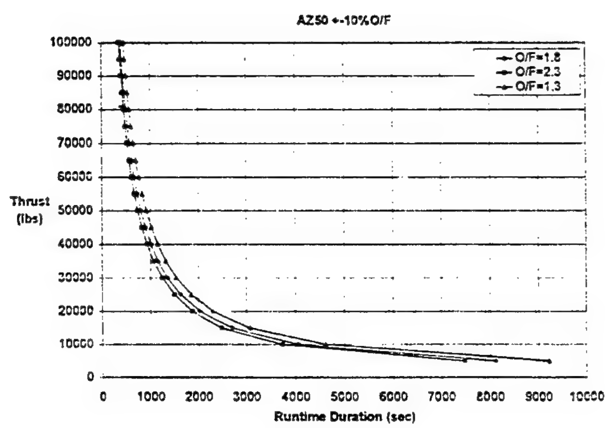

Figure 17. Variation in O:F - AZ50

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Assessment of Hydrazine Monopropellant Plume Conductivity

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Final Report for:
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Assessment of Hydrazine Monopropellant Plume Conductivity

Matthew M. Wiedemer

Introduction

The goal of the work reported here was to extend plume conductivity prediction techniques to monopropellant plumes and to assess the potential for charged particles in the plume for such a thruster. In an attempt to determine potential for charged particles, various aspects of hydrazine thrusters were researched, including rocket thruster basics, hydrazine decomposition chemistry, and hydrazine contamination. Through these studies, it was found that hydrazine has various sources of contamination that could possibly increase the conductivity of the plume. Sodium was found to be a likely source of contamination and chosen to be the test contaminant. A theoretical model of a hydrazine thruster, based on the NASA SP273 computer program, was used to calculate rocket performance and reaction products for a typical hydrazine thruster. These data were then compared to actual performance data and found to be within 20% of real rocket performance data. With the addition of sodium contamination at 200 ppm, the model was run again to find mole fractions of electrons existing in the nozzle. Through these predictions, it was shown that the electron number density was too low for a significantly charged plume.

Acknowledgments

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contact with the Shell 405 catalyst, the decomposition reaction immediately starts, and the catalyst maintains the reaction. This exothermic reaction raises the chamber pressure to generate thrust in the opposite direction of exciting gas flow. The retainer screen prevents the catalyst granules from exiting the chamber, but the gaseous exhaust products of hydrogen, nitrogen, and ammonia continue on through the throat and out of the rocket nozzle.

Hydrazine Contamination

Hydrazine and Shell 405 are not entirely pure, however, and small impurities, especially those substances with a low ionization potential (alkali metals), could cause the hydrazine rocket plume to have charged particles (e.g. free electrons). Handling, storage tanks, and tubing are common sources of contamination of hydrazine. Contamination by the alkali metals is very likely because of their abundance in the earth's crust. Reference 3 reports hydrazine sodium contamination of less than 25 ppm, based on analyses of various samples of hydrazine, and catalyst sodium contamination between 350 to 2200 ppm in samples of Shell 405.

In addition, a chemical analysis of a hydrazine sample was conducted to supplement the data collected from literature. The Chemical and Metallurgical Lab at AEDC performed an atomic emission spectroscopy analysis of an anhydrous hydrazine sample using an ICP (Inductively Coupled Plasma) unit. The contamination of potassium and magnesium were below the detection limits of the ICP, calcium content was negligible, and sodium contamination was 1.62 ppm (see Table 1). Because sodium has a low ionization potential and higher contamination levels in this sample than the other alkali metals, the selected test contaminant for the experiment was sodium. Therefore, a hydrazine contamination level of 200 ppm would overestimate normal contamination levels to compensate for possible contamination from the catalyst.

Theoretical Model

To form a theoretical model of a hydrazine thruster, an equilibrium model for hydrazine decomposition was first constructed. Hydrazine decomposition is known to be non-equilibrium[2], so a comparison of an equilibrium model to the non-equilibrium reality was needed. The NASA SP273 equilibrium model is a computer program used to calculate theoretical rocket performance and equilibrium products using chamber pressure, temperature, and area ratio data. This program requires an input of temperature and pressure, then computes the equilibrium products. With the input of area ratio, the program calculates the equilibrium temperature, pressure, mole fractions, and rocket performance for that area ratio. The CPIA (Chemical Propulsion Information Agency) Liquid Propellant Engine Manual is a

Results/Conclusion

The most significant conclusion of this project was that hydrazine contamination from the alkali metals does not cause the appearance of a large number of electrons in the rocket plume. A theoretical model of a hydrazine monopropellant thruster was constructed based on the SP273 program. This equilibrium model was compared to actual thruster data (both performance and composition were measured) and judged to be valid for this study. The results from the execution of this model, assuming a contamination level of 200 ppm of sodium and temperature up to 1300 K, produced only 10^6 particles of electrons per cubic centimeter. This number is too low to be of significance. Even a sodium contamination of 2000 ppm did not cause a significant increase in electron production.

Recommendations

The NASA SP273 computer program only gave results for the hydrazine decomposition reaction in equilibrium. Results from a non-equilibrium analysis should also be examined, for example, using the NASA LSENS program. This project concluded that the electrons in the rocket plume do not come from sodium contamination, but other sources remain to be examined (e.g., atmospheric ions).

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Figure 2

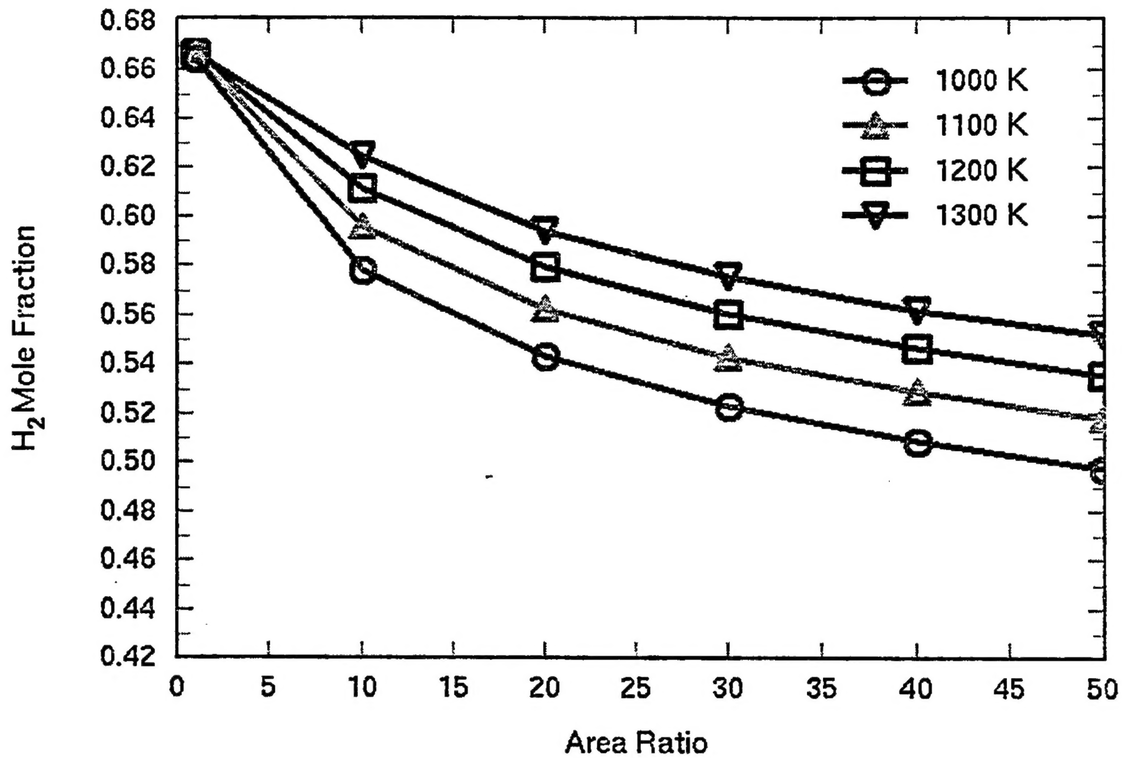

Figure 3